MONTHLY WEATHER REVIEW.

Editor: Prof. Cleveland Abbe. Assistant Editor: Cleveland Abbe, jr.

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The Monthly Weather Review summarizes the current manuscript data received from about 3,500 land stations in the United States and about 1,250 ocean vessels; it also gives the general results of the study of daily weather maps based on telegrams or cablegrams from about 200 North American and 40 European, Asiatic, and oceanic stations.

The hearty interest shown by all observers and correspondents is gratefully recognized.

Acknowledgment is also made of the specific cooperation of the following chiefs of independent, local, or governmental services: R. F. Stupart, Esq., Director of the Meteorological Service of the Dominion of Canada; Señor Manuel E. Pastrana, Director of the Central Meteorological and Magnetic Observatory of Mexico; Camilo A. Gonzales, Director-General of Mexican Telegraphs; Capt. I. S. Kimball, General Superintendent of the United States Life-Saving Service; Commandant Francisco S. Chaves, Director of the Meteorological Service of the Azores, Ponta Delgada, St. Michaels, Azores; W. N. Shaw, Esq., Director Meteorological Office, London; Maxwell Hall, Esq., Government Meteorologist, Kingston, Jamaica; Rev. L. Gangoiti, Director of the Meteorological Observatory of Belen Collegel Havana, Cuba; Luis G. y Carbonell, Director, Meteorologica, Service of Cuba, Havana, Cuba; Rev. José Algué, S. J., Director of the Weather Bureau, Manila Central Observatory, Philippines; Maj. Gen. M. A. Rykachef, Director of the Physical Central Observatory, St. Petersburg, Russia; Carl Ryder, Director, Danish Meteorological Institute, Copenhagen, Denmark.

As far as practicable the time of the seventy-fifth meridian is used in the text of the Monthly Weather Review.

Barometric pressures, both at land stations and on ocean vessels, whether station pressures or sea-level pressures, are reduced, or assumed to be reduced, to standard gravity, as well as corrected for all instrumental peculiarities, so that they express pressure in the standard international system of measures, namely, by the height of an equivalent column of mercury at 32° Fahrenheit, under the standard force, i. e., apparent gravity at sea level and latitude 45°.

FORECASTS AND WARNINGS.

By Prof. E. B. Garriott, in charge of Forecast Division.

September opened with low barometric pressure and severe gales over the British Isles and the northwestern coasts of continental Europe. Over the Atlantic and Pacific oceans pressure was near the normal. An extensive area of high barometer covered western interior portions of the North American Continent, and a storm area was central near the middle Atlantic coast of the United States. The barometer had risen to 30.18 inches at Vladivostok and pressure was decreasing over the interior of Siberia.

During the first decade of the month there was a gradual tho well-marked change from summer to fall types of atmospheric pressure over the great Asiatic continental area. In the United States barometric movements were as a whole abnormally slow, and resulted in a period of stagnated dry weather over middle and northern districts east of the Rocky Mountains during which forest fires caused considerable damage in localities in the North-Central States, and a serious shortage of water was experienced in many sections.

From the 1st to 3d the Atlantic coast storm moved rapidly northeastward to the Canadian Maritime Provinces, and during the succeeding five days apparently crost the Atlantic in the middle latitudes. From the 2d to 4th the interior American high area moved south of east to the middle Atlantic coast attended by a marked fall in temperature and light frost in the upper Lake region, in mountain districts and in lowlands of the Middle Atlantic and New England States. During the 5th and 6th a shallow barometric depression attended by heavy rains moved rapidly from the Gulf States along the Atlantic coast.

On the morning of the 9th there was evidence of a storm formation near the Leeward Islands of the Lesser Antilles, and during the afternoon and night of that date the center of the disturbance past on a northwesterly course near and to the eastward of Porto Rico. By the morning of the 10th the storm-center had advanced to a position north of Porto Rico, and by the morning of the 11th had past to the westward of Turk's Island, where wind velocities estimated at 80 miles, or more, an hour caused destruction of life and property. Continuing a north-of-west course during the 12th and 13th. the center of the storm recurved northward during the 14th and past to the eastward of Nassau, Bahamas. From this region the disturbance moved northeastward between Bermuda and the American coast during the 15th and 16th, past south of the Canadian Maritime Provinces during the 17th, and disappeared over the Atlantic east of Newfoundland after the 18th, after which it apparently merged into an extensive area of low barometer that extended southward from Iceland.

Beginning the morning of the 10th advices regarding this storm were telegraphed daily until the 15th to Atlantic and Gulf ports. The advices of the 10th stated it would be dangerous for vessels during the next few days in the subtropical region of the Atlantic off the south Atlantic coast of the United States, north of the West Indies, and thence to the longitude of Bermuda. In view of a possible recurve of the storm somewhat farther to the westward than the longitude in which the turn to the northward was actually made, advices urged precautionary measures along the coasts of the Florida Peninsula. The exceptional severity of the storm during its westward passage over the Bahamas and attending its subsequent northeasterly course over the Atlantic is shown by reports of vessels that were caught within its vortex.

A remarkable period of dry weather over the northern half of the United States east of the Rocky Mountains set in during the latter portion of August and continued well into the third decade of September. In two or three instances during this period indications that as a rule presage rain partially or wholly failed. The rather remote causes of the dry spell are now recognized. It was not possible to detect and interpret them with previous imperfect knowledge of the operative influence of the greater barometric areas. On September 22d the following forecast based upon radical changes in pressure was issued:

A barometric disturbance will cross the country from about the 24th to 28th, attended by rains that will set in over the central valleys about

the close of this week and extend over the Atlantic States by the beginning of next week. Following the rains there will be a sharp fall in temperature, with frost in the central valleys and Eastern States north of the fortieth parallel.

The rains that attended this disturbance occurred as forecast and relieved the drought in northern and northeastern districts. The frosts that followed its passage extended over the Middle Western States and the States of the Ohio Valley and middle Atlantic coast.

The following comment on this storm and cool wave is made by the Market Growers Journal, Louisville, Ky., of September 30, 1908:

A general area of rain set in over practically the entire Rocky Mountain region the latter half of the week and moved gradually eastward, bringing rain to the Mississippi Valley States by Saturday night. The rain reached the Ohio Valley Sunday night of this week and the indications at this writing are that before this issue reaches our readers the drought in all sections of the country which have been suffering will have been brought to an end. An interesting fact of this rain period is that it was predicted early last week in a bulletin sent out by the Weather Bureau at Washington. * * * The general rains, which marked the end of the drought, are being followed by a period of cold weather which will mark the end of the unusually warm weather of September.

An editorial in the Albany, N. Y., Journal of September 29, reads as follows:

Just now there is in evidence the fulfilment of a forecast made a week ago. Early last week it was announced from Washington that conditions were favorable for the development of a general rain area in this part of the country by about the 28th instant. Because of the long absence of rain that prediction was of unusual interest, and the arrival of the time appointed for its fulfilment was awaited with mingled hope and apprehension.

There was a widespread feeling of relief when the sky became overcast and precipitation began, gradually as it nearly always does after a long period of dry weather.

The Weather Bureau is to be congratulated upon the accuracy of a "long distance" forecast, made at a critical time when all ordinary signs, even to that old standby, the sun's "crossing the line," seemed to fail.

The Kansas City, Mo., Star of September 27, remarks as follows:

An interesting fact about the storm area that is now moving across the country is that it was accurately predicted by the Weather Bureau last Tuesday evening (September 22), when a "long distance" forecast was put out saying that rains would fall in the central valleys about the close of this week, and in the Atlantic States at the beginning of next week, followed by frost north of the fortieth parallel.

The Weather Bureau's forecasts for a week ahead are still in the experimental stage, but they promise to be of great value. They are based on reports of barometric pressures in various parts of the world, indicating the progress of storm areas. Last Tuesday's forecast was based on reports of low barometric pressure at the time in Nome and Sitka, Alaska, and in Honolulu. But the present storm area first appeared over the Rocky Mountain regions with a bank of high barometer all week along the Pacific coast, so that it seems questionable as to whether it came from the conditions on which the Weather Bureau based its long distance forecast of last Tuesday.

The forecast was based on reports for several days preceding the date of its issue. On September 17 Pacific pressure was high over Honolulu and low over Nome. Three days later pressure was high over the Bering Sea region and low over the Hawaiian Islands. It has been observed that pressure changes over the Pacific Ocean forerun by several days certain changes on the Pacific coast and the American Continent as a whole. On September 23 a decided fall in the barometer occurred over the middle and south Pacific coast districts, and on the following day the barometric disturbance appeared, as stated, over the Rocky Mountain districts. It is true that pressure continued high over the north Pacific coast. That was expected. The predictions are based, not necessarily upon the progress of individual storm and high barometer areas, but upon a study of atmospheric conditions over the whole Northern Hemisphere, and more directly, at this season of the year, on the general circulation of the atmosphere over the Pacific and Atlantic oceans. In winter the great continental areas of high barometer, and more especially the Asiatic high area, appear to dominate the general atmospheric changes of the Northern Hemisphere. By a study of the association and interrelation of the greater areas of high and low barometric pressure is the forecasting of weather changes for a week, or more, in advance made possible.

On September 24 West Indian stations were advised of the presence of a cyclonic disturbance east of the Lesser Antilles in latitude about 15° north. On the following morning West Indian ports and Atlantic and Gulf shipping interests were informed that a disturbance of marked intensity near the Leeward Islands of the Lesser Antilles was moving in a westerly direction. During the succeeding two days the hurricane center moved on a west-northwest course, and at 6 a. m. of the 28th past near Port au Prince, Haiti, with a reported minimum barometer reading at that place of 29.24 inches. Continuing a west-northwest course the vortex of the storm advanced over or near the Great Bahama Bank by the close of the month and recurved thence northward over the western Bahamas by October 1, with reported minimum barometric pressure 28.68 inches at 10 a. m., and wind exceeding 80 miles an hour from the south at Nassau. Assuming a northeasterly course the storm then advanced over the Atlantic in the direction of Bermuda. Further advices that may become available regarding this storm will be given in the October, 1908, MONTHLY WEATHER REVIEW.

It is interesting to note that during the present season three West Indian hurricanes have occurred simultaneously with typhoons in Asiatic waters. In the third decade of July a destructive typhoon struck Hongkong, and a severe storm that had its origin in the Caribbean Sea moved northward along the Atlantic coast of the United States. In the second decade of September a typhoon advanced from the Philippine Islands northward along the eastern Asiatic coast, and a hurricane devastated the eastern islands of the Bahama group, moving thence northeastward. In the third decade of September a hurricane swept west-northwest from the Lesser Antilles to the western Bahamas and recurved thence northeastward, and a typhoon past from the Philippine Islands westward over the China Sea.

BOSTON FORECAST DISTRICT.*

[New England.]

The month was unusually warm and dry. The drought that prevailed was one of the most severe in many years, particularly in Vermont, and the average rainfall for New England was the smallest for September since the establishment of the New England Climatological Service in 1888. The first killing frost of the season occurred in Maine, New Hampshire, Vermont, and parts of Massachusetts on the 16th. Frost warnings were sent to cranberry growers on the 15th. Storm warnings were issued on the 1st, 17th, and 28th, and there were no storms without warnings.—*J. W. Smith, District Forecaster.*

NEW ORLEANS FORECAST DISTRICT.*

[Louisiana, Texas, Oklahoma, and Arkansas.]

A disturbance for which storm warnings were ordered appeared in the west Gulf the morning of the 17th. This disturbance was attended by a wind velocity of 64 miles an hour at Galveston, Tex., and by general showers over Louisiana, eastern Texas, Oklahoma, and Arkansas. The first frost of the season was reported in Oklahoma and northeastern Texas on the 28th, for most of which warnings had been issued.—*I. M. Cline, District Forecaster.*

LOUISVILLE FORECAST DISTRICT.*

[Kentucky and Tennessee.]

The month was remarkable on account of the severe drought and unusual warmth that prevailed, except in southeastern Tennessee where rainfall was about normal. Over the balance of Kentucky and Tennessee practically no rain fell from the

5th to 27th. A decided change to colder came with the rainstorm of the 27th, and the last three days of the month were unusually cold, with frost generally in Kentucky and parts of Tennessee. Special warnings were issued for the frost.—*F. J. Walz, District Forecaster.*

CHICAGO FORECAST DISTRICT.*

[Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas, and Montana.]

Except during the last few days of the month September was unusually warm. The change to cooler weather set in over the Western States on the 25th and advanced slowly eastward, bringing unseasonably cold weather and general frosts for which warnings were issued well in advance. Frost warnings were again issued on the 30th in advance of another cool area. Special frost warnings were issued to the cranberry marshes of Wisconsin on the 1st, 2d, and 6th, and in each case frost and freezing temperatures were reported in the bogs. The drought conditions continued from the previous summer months, and they were not effectually broken until the passage of the storm of the last week. The only disturbance that justified storm warnings crost the upper Lakes on the 30th, and warnings were issued for this storm on the morning of that day.

The following action was taken by the South Dakota State Board of Agriculture in connection with a special forecast telegraphed from Chicago to the Local Office of the Weather Bureau at Huron, S. Dak., on September 8:

By resolution of the State Board of Agriculture, it is my duty and pleasure to express to you, and through you to the U. S. Weather Bureau, our sin ere thanks for the long forecast given us for the week of our Fair. It was of great value for us to know this as it saved much expense in preparing for rain as we felt we should. Besides this it was a great relief of mind to the management to know that we could expect such fine weather. J. W. CAMPBELL, *President.*

H. J. Cox, Professor and District Forecaster.

DENVER FORECAST DISTRICT.*

[Wyoming, Colorado, Utah, New Mexico, and Arizona.]

Except during the closing week the month was warm and dry. From the 23d to 26th a heavy storm of snow and rain moved from Wyoming to southern New Mexico. The storm was followed by one of the most severe cold spells on record during September in eastern portions of Wyoming, Colorado, and New Mexico. Timely warnings of frost and freezing temperature were issued in connection with the cold spell.—*P. McDonough, Local Forecaster, temporarily in charge.*

SAN FRANCISCO FORECAST DISTRICT.†

[California and Nevada.]

The most striking feature of the month was the storm that prevailed over southern California on the 23d to 25th. Generally speaking the rainfall was the heaviest during September since records have been kept. It varied in amount from half an inch to several inches. The raisin-making section had ample warnings of the rains and the benefit of the service has been acknowledged. No frost nor storm warnings were issued during the month.—*A. G. McAdie, Professor and District Forecaster.*

PORTLAND, OREG., FORECAST DISTRICT.†

[Oregon, Washington, and Idaho.]

The month was unusually dry in western and northern sections, and temperature was slightly above normal east of the Cascade Mountains. A moderate disturbance crost the northern portion of the district the last day of the month. Light frosts occurred on the 23d and 24th and heavy frosts on the 25th and 26th. Warnings of the storm and frosts were issued in time to be of service to those interested in them.—*E. A. Beals, District Forecaster.*

RIVERS AND FLOODS.

The feature of the month was the general drought that prevailed over the middle and northern districts east of the Rocky Mountains. Little or no rain fell over this extensive area until the end of the month, and all streams, except the Mississippi and Missouri, were at very low stages. The two larger rivers were not lower than usual for the season of the year.

The drought conditions were most severe in the Ohio Valley and the Middle Atlantic States, and in many places rivers were lower than ever before. Navigation was practically suspended on the Ohio, and many manufacturing plants in the upper Ohio Valley were compelled to suspend operations on account of lack of water.

Delayed reports of the flood of August and early September in the rivers of eastern South Carolina show that the damage caused thereby amounted to over $900,000, divided as follows: Property loss, excluding crops, $200,000; losses of crops, $700,000. The losses due to erosion of land and suspension of business were reported great, but detailed reports were not available.

The highest and lowest water, mean stage, and monthly range at 211 river stations are given in Table IV. Hydrographs for typical points on seven principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.—*H. C. Frankenfield, Professor of Meteorology.*

* Morning forecasts made at district center; night forecasts made at Washington, D. C.

† Morning and night forecasts made at district center.

SPECIAL ARTICLES, NOTES, AND EXTRACTS.

RÉSUMÉ OF EXPERIMENTS IN AERODYNAMICS

By Dr. A. F. ZAHM. Dated Washington, D. C., August 24, 1908.

INTRODUCTION.

Aerodynamics may be defined broadly as the science of motion of air, or an aeriform fluid. Commonly air alone is implied in the word. This is especially true when the name is used by engineers. With them it is the analog of hydraulics, which is the science of motion of water. Both sciences treat not only of the movement of their peculiar media, but also of its effects on objects, or machinery, connected with the fluids.

An important function of aerodynamics is to determine the velocity and stress of air at every point of this medium, when it flows past an obstacle, the physical conditions of the fluid being given or observed by means of suitable instruments. From the point-velocity the stream-lines may be mapped; from the point-stress about an object the resultant pressure and friction may be found by integrating over its surface.

Equivalent results may be obtained if the object move against the fluid, since only the relative motion is of consequence. Devices are in use, also, for revealing these integrated effects directly, without first finding the point-velocity and point-stress. Some of these will be described presently.

Experimental aerodynamics may be studied in its elements, as distinguished from its applications, by considering it under these heads: (1) velocity and stream-lines; (2) normal stress and resultant pressure; (3) shearing stress and resultant friction; (4) combined pressure and friction. To trace the development of even this much of the science would require a large volume.

The following pages present a brief sketch of such of the writer's experiments as may be classed under the above heads,

no reference being made to analytical studies, or to any applications in aeronautics, or engineering. A fuller account of the studies here outlined may be found in the following papers by the present writer:

"Measurement of air velocity and pressure," Physical Review, December, 1903.

"Atmospheric friction with special reference to aeronautics," Bulletin of the Philosophical Society of Washington, Vol. XIV.

"Law of resistance of rods and wires," in "Navigating the air," Doubleday, Page & Co., 1907.

"Resistance of the air determined at speeds below one thousand feet a second," printed privately as a doctor's thesis.

GENERAL METHODS.

Two general methods may be used to secure relative motion of the air and model. In one case the object is placed in a wind, either natural or artificial; in the other case it moves against still air, either by riding on a car or whirling arm, or by falling, or by propulsion from a gun. In both cases a uniform relative wind is usually desired. This can not be obtained regularly out of doors, except for very high speeds, because the atmosphere is usually in irregular motion. Hence indoor experiments are more reliable and, moreover, the flow of air can be more definitely specified.

To secure a uniform wind of constant velocity, a wind tunnel is employed. This may be a wooden tunnel, a yard or two in diameter, having a suction fan at one end to generate a current, having a screen or "honey-comb," at the other, to straighten the inflowing air. A fine mesh screen or two may eliminate eddies from the air-stream and deliver it to the tunnel in fairly uniform current, but with diminished speed. A honey-comb made of sheet metal, is preferable, for this straightens the flow without diminishing the speed materially. If the tunnel be horizontal, it should be placed well above the floor and away from the wall, to symmetrize the wind-flow. With such a tunnel, as the writer has found, it is possible to maintain a uniform velocity, constant to 1 per cent, by use of an electric fan controlled by a boy with a tachometer and resistance coil.

The reverse of a wind tunnel is a long room thru which the model moves on a car at constant speed, the room being closed and the car being so designed as not to disturb the air preceptibly, near the model. No such plant has ever been used on a large scale, but it is a great desideratum for exact measurements of air resistance, especially on objects intended for standards of comparison, and for the determination of physical constants. In such a room it would require a short period for the car, starting from rest, to attain full speed, during which period the entire volume of air in front of the car would be slightly compressed and reach its steady state, after which the circumstances of motion would remain constant and definable. One might use for this purpose a long railroad tunnel provided with light doors to close its ends and keep the air still during the short period of experimentation. A closed circular tunnel also might be used, the model being carried either on a car, or on a whirling table arm. But here arise the objections of drift-wind and centrifugal force, unless the tunnel be very long.

Assuming, then, that a plant is available, furnishing a uniform constant relative velocity of air and object, we may proceed to more detailed studies.

DETERMINATION OF VELOCITY AND STREAM-LINE.

Having a uniform artificial wind, the next requsite is an instrument for measuring its velocity at all points, not only in the unchecked stream, but also near the model. The first measurement is easy, the latter much less so. The speed in the unchecked stream may be found by any ordinary good anemometer; but near the model it can be found only by special devices presently to be described.

To measure the wind-speed in a uniform current, the writer has devised a pressure-tube anemometer whose observed indications seem to conform to those computed for it from theory. It is an adaptation of the Pitot tube, and consists essentially of a double pressure-nozzle combined with a delicate pressure-gage.

A "pressure-tube" held along stream transmits the impactual pressure of the air from the front nozzle or open end of the tube, and the static pressure from the side nozzle or slot in the side of a coaxial outer tube, to the cups of a differential pressure-gage. These cups, symmetrical in size and placement, are inverted over coal oil, and counterpoised from a meter-stick. A sliding weight, and a pointer measure the difference between the static and kinetic pressures of the two nozzles; and from this difference can be computed the speed of the air, if its density be known either by observation or by computation from its temperature, pressure, and humidity.

This instrument when placed in a uniform current measures the speed very accurately and is adapted to a wide range of velocities. In a sinuous current, however, it is unreliable, because such a current does not strike the impact nozzle squarely, nor flow undisturbed over the static nozzle. If the pressure-tube were mounted on a universal wind-vane, so as always to point along stream, it might be serviceable even for a varying wind. But such currents can not be specified, and hence are not used in precise measurements.

In designing a Pitot tube, either for air or water, it is of cardinal importance that the impact nozzle face the wind, while the static nozzle be so placed as to allow the air to glide over it with undisturbed stream-lines. When, as sometimes occurs, the static nozzle is a simple tube placed across stream, suction is produced. This can be prevented by terminating the tube with a thin flange-like disk, as done with good effect by the writer, and by Doctors Finzi and Soldati of Milan, Italy.

The velocity at any point of the air stream, to within an inch or two of the model, may be measured by use of the pressure-tube anemometer if its nozzle be made small; but for points immediately adjacent to the model, no very accurate and convenient instrument has been invented. A device that gives the speed approximately, even very close to the surface, is intermittent photography of fine particles floating in the air stream. A very elegant method invented by Professor Marey, makes use of narrow smoke streams to manifest the stream-lines and velocity thruout the medium. A hollow comb planted across the current, and vibrating ten times a second, emits from the ends of hollow teeth, wavy smoke streams of a quarter-inch diameter, which are photographed instantaneously. Evidently the length of a wave indicates the local speed, while the general course of each stream shows the direction of flow.

DETERMINATION OF NORMAL STRESS AND RESULTANT PRESSURE.

The normal pressure may have to be measured either in still or in moving air. In still air it is determined by the ordinary barometer; but in moving air this instrument may give false readings owing to suction, unless the barometer drift with the current, as when carried in a balloon. To obviate the error caused by suction when an ordinary barometer is placed in the wind, the instrument may be provided with a stream-line static nozzle.[1]

The resultant pressure on any body may be found by integrating the normal stress of the air all over the surface of the body. In this case the absolute normal pressure is not required, but merely the relative pressure at all parts of the body. For example, let it be required to determine the resultant wind pressure on a torpedo-shaped body pointing along stream. Holes are made at various points of a longitudinal element of

[1] See also, Abbe, Treatise on Meteorological Apparatus and Methods. Report Chief Signal Officer, 1887, pt. 2. p. 215-16, 253-7.

the surface. One nozzle of a pressure-tube anemometer is then permanently connected with one of the holes, while the other nozzle is connected successively to each of the other holes, the conditions of flow being constant. Having thus measured the differential pressure at all points, the total or resultant pressure may be found by summing over the surface. This summation is zero in the case of a perfect fluid, but for natural fluids the resultant is always an appreciable quantity.

It may be remarked in passing that the resultant pressure, as determined in the manner above, is not always the same thing as the resultant wind-force on the object, the latter being the sum of the resultant pressure and resultant friction, all taken in the line of the wind. Sometimes the total wind-force alone is required, but for the scientific designing of wind-shapes, it is important to study the point-pressure and point-friction at all parts of the body's surface. It may be noted that in the limiting cases for thin planes set edgewise to the current the wind-force is all friction, and when set crosswise it is all pressure; but in general the wind force may comprise both elements, pressure and friction, to such an extent as to make their separate study desirable.

DETERMINATION OF SHEARING STRESS AND RESULTANT FRICTION.

No exact method has been devised for measuring directly the shearing stress of moving air at any point of the fluid; but the total shearing resistance on bodies in relative motion with the air may be measured, and from the law of this total friction the point-shearing stress may be deduced. This has been done by various physicists, who have determined the viscosity or internal shearing stress of moving air, and also the sliding friction at the boundary surface of bodies. These determinations, however, were made for low velocities.

Until recently the frictional resistance of bodies having rapid motion relatively to the air, was supposed, even by prominent experimenters, to be inappreciable. Langley, who measured the drift of planes at low angles of flight and at speeds up to 66 feet per second, reported in his published experiments no friction whatever, and declared it a negligible quantity for bodies of all shapes. Maxim reached a like conclusion. The writer found, however, that for bodies of fair outline, the friction or skin-resistance, is approximately one-half of the entire resistance. Roughly speaking, he found it to be as great for air as for water, in proportion to their densities, the measurements being made at various speeds from 5 to 40 feet per second.

In order to determine the tangential resistance of the air flowing freely over smooth surfaces, various skin-friction planes were suspended in a uniform current of air in a wind tunnel, by means of fine steel wires fastened to the top of the laboratory. As the wind-force moved the plane endwise, the displacement was shown by the motion of a sharp pointer attached to one of the wires and traveling over a fine scale lying on top of the tunnel. Thus, the swing of the plane could be accurately determined and the force on the plane could be computed, being directly proportional to the displacement of the pointer along the scale.

The friction on a plane of given length was first determined for various wind-speeds. To do this a smooth pine board measuring 4 feet long by 25.5 inches wide by 1 inch thick and provided with sharp "prow" pieces fore and aft was employed, just as an ordinary skin-friction plane is used in the water. The total resistance was observed at all speeds from 5 to 40 feet per second. Then the board was removed, the "prows" placed together, their united resistance measured for the same speeds, and this subtracted from the preceding values. The difference gave the skin-friction on the 4-foot plane alone for all the above speeds.

Having found the friction at many speeds, on a given plane, the data were plotted on logarithmic section paper. The resulting diagram was a straight line. This proves that for a fixt plane and moving air the law of friction for the actual range of velocities, may be exprest by the equation $F=av^n$, in which F is the observed friction, v the wind speed, a and n numerical constants given by the position and slope of the line on the section paper. The general value found for n from many experiments with smooth planes of various length and quality of surface coating, was $n=1.85$. It may then be concluded that the law of friction for the given range and conditions of experiment is exprest by the formula

$$F=av^{1.85}$$

in which a remains still to be determined.

It was found that tho a is constant for a plane of given length, subjected to various speeds, its value diminishes slightly with the length of plane, as might be expected. To determine a, therefore, all the other conditions were kept constant while the plane was varied in length from 2 to 16 feet, by dowelling pieces together accurately. Comparing the resistances determined for these various lengths, it was found that the coefficient of friction, a, can be exprest as a function of the length, by an equation of the form $a=0.00000778\ l^{0.93}$, l being the length of surface. Hence, the entire skin-friction on a plane surface 1 foot wide and l feet long is given by the equation:

$$F \text{ in lbs. p. sq. foot of surface skin.} \left\{ \begin{array}{l} F=0.00000778\ l^{0.93}\ v^{1.85}\ (v \text{ in ft. p. sec.}). \\ F=0.00000158\ l^{0.93}\ v^{1.85}\ (v \text{ in mi. p. h.}). \end{array} \right.$$

Of course this value of F must be doubled for a material plane of length l, and width 1 foot, since a material plane has two sides.

In order to facilitate the computation of skin-friction in practise, Table 1 has been derived from the formula giving the *average skin-friction per square foot* for planes varying in length from 1 to 32 feet. Only the values in heavy type lie within the range of experiments above described.

TABLE 1.—*Skin-friction per square foot for various speeds and lengths of surface.*

Wind speed.	Average friction in pounds per square foot.					
	1′ plane.	2′ plane.	4′ plane.	8′ plane.	16′ plane.	32′ plane.
Miles per hour.						
5	0.000303	**0.000289**	**0.000275**	**0.000262**	**0.000250**	0.000238
10	0.00112	**0.00105**	**0.00101**	**0.000967**	**0.000922**	0.000878
15	0.00237	**0.00226**	**0.00215**	**0.00205**	**0.00195**	0.00186
20	0.00402	**0.00384**	**0.00365**	**0.00349**	**0.00332**	0.00317
25	0.00606	**0.00579**	**0.00551**	**0.00527**	**0.00501**	0.00478
30	0.00850	0.00810	0.00772	0.00736	0.00701	0.00668
35	0.01130	0.0108	0.0103	0.0098	0.00932	0.00888
40	0.0145	0.0138	0.0132	0.0125	0.0125	0.0114
50	0.0219	0.0209	0.0199	0.0190	0.0181	0.0172
60	0.0307	0.0293	0.0279	0.0265	0.0253	0.0242
70	0.0407	0.0390	0.0370	0.0353	0.0337	0.0321
80	0.0522	0.0500	0.0474	0.0452	0.0431	0.0411
90	0.0650	0.0621	0.0590	0.0563	0.0536	0.0511
100	0.0792	0.0755	0.0719	0.0685	0.0652	0.0622

Finally all the conditions of experiment were kept constant except the quality of surface of the skin-friction boards. Practically the same skin-friction was observed whether the board was covered with dry glossy varnish or with wet sticky varnish, with calendered or uncalendered paper, with glazed cambric, sheet zinc, etc. But when the plane was covered with coarse buckram, having sixteen meshes to the inch, the skin-friction, at 10 feet per second, was 10 to 15 pe[illegible] greater than for the smooth wooden surface; and the fri[illegible] as the square of the wind velocity.

The fact that, for some surfaces, the coeffic[illegible] of air and water are roughly as their densiti[illegible] able importance. For the impactual resist[illegible] the densities of the two fluids. Hence the d[illegible] water-resistance measurements may be fai[illegible] estimate the air-resistance on models of va[illegible]

no reference being made to analytical studies, or to any applications in aeronautics, or engineering. A fuller account of the studies here outlined may be found in the following papers by the present writer:

"Measurement of air velocity and pressure," Physical Review, December, 1903.

"Atmospheric friction with special reference to aeronautics," Bulletin of the Philosophical Society of Washington, Vol. XIV.

"Law of resistance of rods and wires," in "Navigating the air," Doubleday, Page & Co., 1907.

"Resistance of the air determined at speeds below one thousand feet a second," printed privately as a doctor's thesis.

GENERAL METHODS.

Two general methods may be used to secure relative motion of the air and model. In one case the object is placed in a wind, either natural or artificial; in the other case it moves against still air, either by riding on a car or whirling arm, or by falling, or by propulsion from a gun. In both cases a uniform relative wind is usually desired. This can not be obtained regularly out of doors, except for very high speeds, because the atmosphere is usually in irregular motion. Hence indoor experiments are more reliable and, moreover, the flow of air can be more definitely specified.

To secure a uniform wind of constant velocity, a wind tunnel is employed. This may be a wooden tunnel, a yard or two in diameter, having a suction fan at one end to generate a current, having a screen or "honey-comb," at the other, to straighten the inflowing air. A fine mesh screen or two may eliminate eddies from the air-stream and deliver it to the tunnel in fairly uniform current, but with diminished speed. A honey-comb made of sheet metal, is preferable, for this straightens the flow without diminishing the speed materially. If the tunnel be horizontal, it should be placed well above the floor and away from the wall, to symmetrize the wind-flow. With such a tunnel, as the writer has found, it is possible to maintain a uniform velocity, constant to 1 per cent, by use of an electric fan controlled by a boy with a tachometer and resistance coil.

The reverse of a wind tunnel is a long room thru which the model moves on a car at constant speed, the room being closed and the car being so designed as not to disturb the air preceptibly, near the model. No such plant has ever been used on a large scale, but it is a great desideratum for exact measurements of air resistance, especially on objects intended for standards of comparison, and for the determination of physical constants. In such a room it would require a short period for the car, starting from rest, to attain full speed, during which period the entire volume of air in front of the car would be slightly compressed and reach its steady state, after which the circumstances of motion would remain constant and definable. One might use for this purpose a long railroad tunnel provided with light doors to close its ends and keep the air still during the short period of experimentation. A closed circular tunnel also might be used, the model being carried either on a car, or on a whirling table arm. But here arise the objections of drift-wind and centrifugal force, unless the tunnel be very long.

Assuming, then, that a plant is available, furnishing a uniform constant relative velocity of air and object, we may proceed to more detailed studies.

DETERMINATION OF VELOCITY AND STREAM-LINE.

Having a uniform artificial wind, the next requsite is an instrument for measuring its velocity at all points, not only in the unchecked stream, but also near the model. The first measurement is easy, the latter much less so. The speed in the unchecked stream may be found by any ordinary good anemometer; but near the model it can be found only by special devices presently to be described.

To measure the wind-speed in a uniform current, the writer has devised a pressure-tube anemometer whose observed indications seem to conform to those computed for it from theory. It is an adaptation of the Pitot tube, and consists essentially of a double pressure-nozzle combined with a delicate pressure-gage.

A "pressure-tube" held along stream transmits the impactual pressure of the air from the front nozzle or open end of the tube, and the static pressure from the side nozzle or slot in the side of a coaxial outer tube, to the cups of a differential pressure-gage. These cups, symmetrical in size and placement, are inverted over coal oil, and counterpoised from a meter-stick. A sliding weight, and a pointer measure the difference between the static and kinetic pressures of the two nozzles; and from this difference can be computed the speed of the air, if its density be known either by observation or by computation from its temperature, pressure, and humidity.

This instrument when placed in a uniform current measures the speed very accurately and is adapted to a wide range of velocities. In a sinuous current, however, it is unreliable, because such a current does not strike the impact nozzle squarely, nor flow undisturbed over the static nozzle. If the pressure-tube were mounted on a universal wind-vane, so as always to point along stream, it might be serviceable even for a varying wind. But such currents can not be specified, and hence are not used in precise measurements.

In designing a Pitot tube, either for air or water, it is of cardinal importance that the impact nozzle face the wind, while the static nozzle be so placed as to allow the air to glide over it with undisturbed stream-lines. When, as sometimes occurs, the static nozzle is a simple tube placed across stream, suction is produced. This can be prevented by terminating the tube with a thin flange-like disk, as done with good effect by the writer, and by Doctors Finzi and Soldati of Milan, Italy.

The velocity at any point of the air stream, to within an inch or two of the model, may be measured by use of the pressure-tube anemometer if its nozzle be made small; but for points immediately adjacent to the model, no very accurate and convenient instrument has been invented. A device that gives the speed approximately, even very close to the surface, is intermittent photography of fine particles floating in the air stream. A very elegant method invented by Professor Marey, makes use of narrow smoke streams to manifest the stream-lines and velocity thruout the medium. A hollow comb planted across the current, and vibrating ten times a second, emits from the ends of hollow teeth, wavy smoke streams of a quarter-inch diameter, which are photographed instantaneously. Evidently the length of a wave indicates the local speed, while the general course of each stream shows the direction of flow.

DETERMINATION OF NORMAL STRESS AND RESULTANT PRESSURE.

The normal pressure may have to be measured either in still or in moving air. In still air it is determined by the ordinary barometer; but in moving air this instrument may give false readings owing to suction, unless the barometer drift with the current, as when carried in a balloon. To obviate the error caused by suction when an ordinary barometer is placed in the wind, the instrument may be provided with a stream-line static nozzle.[1]

The resultant pressure on any body may be found by integrating the normal stress of the air all over the surface of the body, In this case the absolute normal pressure is not required, but merely the relative pressure at all parts of the body. For example, let it be required to determine the resultant wind pressure on a torpedo-shaped body pointing along stream. Holes are made at various points of a longitudinal element of

[1] See also, Abbe, Treatise on Meteorological Apparatus and Methods. Report Chief Signal Officer, 1887, pt. 2. p. 215-16, 253-7.

the surface. One nozzle of a pressure-tube anemometer is then permanently connected with one of the holes, while the other nozzle is connected successively to each of the other holes, the conditions of flow being constant. Having thus measured the differential pressure at all points, the total or resultant pressure may be found by summing over the surface. This summation is zero in the case of a perfect fluid, but for natural fluids the resultant is always an appreciable quantity.

It may be remarked in passing that the resultant pressure, as determined in the manner above, is not always the same thing as the resultant wind-force on the object, the latter being the sum of the resultant pressure and resultant friction, all taken in the line of the wind. Sometimes the total wind-force alone is required, but for the scientific designing of wind-shapes, it is important to study the point-pressure and point-friction at all parts of the body's surface. It may be noted that in the limiting cases for thin planes set edgewise to the current the wind-force is all friction, and when set crosswise it is all pressure; but in general the wind force may comprise both elements, pressure and friction, to such an extent as to make their separate study desirable.

DETERMINATION OF SHEARING STRESS AND RESULTANT FRICTION.

No exact method has been devised for measuring directly the shearing stress of moving air at any point of the fluid; but the total shearing resistance on bodies in relative motion with the air may be measured, and from the law of this total friction the point-shearing stress may be deduced. This has been done by various physicists, who have determined the viscosity or internal shearing stress of moving air, and also the sliding friction at the boundary surface of bodies. These determinations, however, were made for low velocities.

Until recently the frictional resistance of bodies having rapid motion relatively to the air, was supposed, even by prominent experimenters, to be inappreciable. Langley, who measured the drift of planes at low angles of flight and at speeds up to 66 feet per second, reported in his published experiments no friction whatever, and declared it a negligible quantity for bodies of all shapes. Maxim reached a like conclusion. The writer found, however, that for bodies of fair outline, the friction or skin-resistance, is approximately one-half of the entire resistance. Roughly speaking, he found it to be as great for air as for water, in proportion to their densities, the measurements being made at various speeds from 5 to 40 feet per second.

In order to determine the tangential resistance of the air flowing freely over smooth surfaces, various skin-friction planes were suspended in a uniform current of air in a wind tunnel, by means of fine steel wires fastened to the top of the laboratory. As the wind-force moved the plane endwise, the displacement was shown by the motion of a sharp pointer attached to one of the wires and traveling over a fine scale lying on top of the tunnel. Thus, the swing of the plane could be accurately determined and the force on the plane could be computed, being directly proportional to the displacement of the pointer along the scale.

The friction on a plane of given length was first determined for various wind-speeds. To do this a smooth pine board measuring 4 feet long by 25.5 inches wide by 1 inch thick and provided with sharp "prow" pieces fore and aft was employed, just as an ordinary skin-friction plane is used in the water. The total resistance was observed at all speeds from 5 to 40 feet per second. Then the board was removed, the "prows" placed together, their united resistance measured for the same speeds, and this subtracted from the preceding values. The difference gave the skin-friction on the 4-foot plane alone for all the above speeds.

Having found the friction at many speeds, on a given plane, the data were plotted on logarithmic section paper. The resulting diagram was a straight line. This proves that for a fixt plane and moving air the law of friction for the actual range of velocities, may be exprest by the equation $F=av^n$, in which F is the observed friction, v the wind speed, a and n numerical constants given by the position and slope of the line on the section paper. The general value found for n from many experiments with smooth planes of various length and quality of surface coating, was $n=1.85$. It may then be concluded that the law of friction for the given range and conditions of experiment is exprest by the formula

$$F=av^{1.85}$$

in which a remains still to be determined.

It was found that tho a is constant for a plane of given length, subjected to various speeds, its value diminishes slightly with the length of plane, as might be expected. To determine a, therefore, all the other conditions were kept constant while the plane was varied in length from 2 to 16 feet, by dowelling pieces together accurately. Comparing the resistances determined for these various lengths, it was found that the coefficient of friction, a, can be exprest as a function of the length, by an equation of the form $a=0.00000778\,l^{0.93}$, l being the length of surface. Hence, the entire skin-friction on a plane surface 1 foot wide and l feet long is given by the equation:

$$F \text{ in lbs. p. sq. foot of surface skin.} \begin{cases} F=0.00000778\, l^{0.93}\, v^{1.85} \ (v \text{ in ft. p. sec.}). \\ F=0.00000158\, l^{0.93}\, v^{1.85} \ (v \text{ in mi. p. h.}). \end{cases}$$

Of course this value of F must be doubled for a material plane of length l, and width 1 foot, since a material plane has two sides.

In order to facilitate the computation of skin-friction in practise, Table 1 has been derived from the formula giving the *average skin-friction per square foot* for planes varying in length from 1 to 32 feet. Only the values in heavy type lie within the range of experiments above described.

TABLE 1.—*Skin-friction per square foot for various speeds and lengths of surface.*

Wind speed.	Average friction in pounds per square foot.					
	1′ plane.	2′ plane.	4′ plane.	8′ plane.	16′ plane.	32′ plane.
Miles per hour.						
5	0.000303	**0.000289**	**0.000275**	**0.000262**	**0.000250**	0.000238
10	0.00112	**0.00105**	**0.00101**	**0.000967**	**0.000922**	0.000878
15	0.00237	**0.00226**	**0.00215**	**0.00205**	**0.00195**	0.00186
20	0.00402	**0.00384**	**0.00365**	**0.00349**	**0.00332**	0.00317
25	0.00606	**0.00579**	**0.00551**	**0.00527**	**0.00501**	0.00478
30	0.00850	0.00810	0.00772	0.00736	0.00701	0.00668
35	0.01130	0.0108	0.0103	0.0098	0.00932	0.00888
40	0.0145	0.0138	0.0132	0.0125	0.0125	0.0114
50	0.0219	0.0209	0.0199	0.0190	0.0181	0.0172
60	0.0307	0.0293	0.0279	0.0265	0.0253	0.0242
70	0.0407	0.0390	0.0370	0.0353	0.0337	0.0321
80	0.0522	0.0500	0.0474	0.0452	0.0431	0.0411
90	0.0650	0.0621	0.0590	0.0563	0.0536	0.0511
100	0.0792	0.0755	0.0719	0.0685	0.0652	0.0622

Finally all the conditions of experiment were kept constant except the quality of surface of the skin-friction boards. Practically the same skin-friction was observed whether the board was covered with dry glossy varnish or with wet sticky varnish, with calendered or uncalendered paper, with glazed cambric, sheet zinc, etc. But when the plane was covered with coarse buckram, having sixteen meshes to the inch, the skin-friction, at 10 feet per second, was 10 to 15 per cent greater than for the smooth wooden surface; and the friction increased as the square of the wind velocity.

The fact that, for some surfaces, the coefficients of friction of air and water are roughly as their densities is of considerable importance. For the impactual resistances also vary as the densities of the two fluids. Hence the data obtained from water-resistance measurements may be fairly well applied to estimate the air-resistance on models of various shapes.

COMBINED PRESSURE AND FRICTION.

The total resistance of various regular geometrical forms was also measured. Among the forms were spheres, rods, wires, spindles, and wedge-shaped cylinders. An important purpose in studying the two latter shapes was to determine the forms of least resistance, and the relative magnitudes of pressure and friction on such forms.

To determine the spindle form of least resistance a number of models were made, of ogival outline and symmetrical in bow and stern. These were suspended in turn from the sheltered vertical arm of a bell-crank wind-balance, having a graduated horizontal arm outside and above the tunnel. Sliding weights on the horizontal arm outside were made to counterbalance the wind thrust against the models held by the sheltered vertical arm inside the tunnel. In this way the total resistance of each spindle was determined for many speeds.

On comparing the resistances at the same speed, of various symmetrical spindles, an interesting effect was noted. The spindles, which were all 4 inches in diameter at their middle, and of increasing lengths of ogive, showed a total resistance which decreased rapidly as the short models grew in length, but presently became a minimum, then increased as the models grew longer and more tapering. Among the symmetrical spindles the form of least resistance was found to be the one having a "12-caliber" outline, i. e., its contour from prow to stern is a circular arc struck with a radius of twelve diameters. A form of considerably less resistance was found when a 2-caliber bow was combined with a 12-caliber stern, the resistance in this case being about one-eighth that of a 4-inch disk. In this model the length was roughly five times the major diameter. Thus it appears that a well-designed torpedo shape is the form of least resistance for air as well as for water.

Having found the symmetrical form of least resistance, by gradually lengthening the shorter form, the torpedo shape was derived from that by gradually shortening its bow. By this procedure, the friction on the bow was diminished more than the head pressure was increased until the form of least resistance was attained. The same treatment could not be applied to the stern of the model without increasing the suction more than the friction was diminished. It was also observed that if the tail of the torpedo were placed frontward, the total resistance was approximately doubled.

Similar results were obtained with the wedge-shaped ogival cylinders placed across the current. Their thickness being kept constantly 1 inch, and starting with the blunt ones, their total resistance was found to fall rapidly with increase in width of the wedge. The symmetrical form of least resistance was found in the 40-caliber model, whose width is about 11 inches, or eleven times the thickness. Still less resistance was found on the shape having a 5-caliber bow and a 40-caliber stern, the total resistance on this being about one-eighth that of its major section. The reasons for the observed phenomena are about the same for the two classes of models, the spindles and wedges.

An effort was made to compare the resultant frictional and pressural forces on each of the wedges, as also on each of the spindles. As the models were lengthened the friction grew and the pressure waned. They became equal when the model was about passing its most favorable shape.

The same current and bell-crank wind-balance above referred to were used to find the resistance of rods and wires varying in diameter from 2 inches down to the smallest standard gage. The balance-arm and frame holding the wires were carefully inclosed in sheet metal shields, so shaped as not to disturb the current materially. The resistance of the rods varied directly as their diameters, but the coefficient of resistance of the wires increased as their diameters diminished, thus indicating that a molecularly fine wire must have a considerable finite resistance. Incidentally it was observed that the resistance of both rods and wires varied directly as the square of the wind-speed, a well-known relation at low velocities. The quantitative results of these experiments are to be published after the measurements have been extended to still finer wires.

A special method was devised to measure the resistance of the air to some shapes moving at speeds below 1,000 feet per second. The body was shot from a cannon horizontally thru the air, and its retardation found. From this and the known mass of the projectile, its resistance was computed. The accuracy of the method, therefore, depends upon the precision of measurement of the retardation.

To secure greater accuracy in this latter research some novel features were introduced. The experiment was made in a closed room in homogenous still air. The bullets were light wooden spheres, some solid, others hollow, whose retardation is twenty to forty times greater, and hence as many times more precisely measurable, than solid steel ones. A recording chronograph was devised which, without impeding the bullet, measured its time of passage from point to point accurately to one five-hundred-thousandth of a second. Across the path of the projectile at intervals of 7 feet were thrown three ribbons of sunlight, each one-hundredth of an inch thick. The bullet emerging from the gun past thru a number of screens, which stopt the blast, then cut the sunbeams squarely and landed in a box of cotton. The beams, suitably diverted, past thru an aperture in a tall columnar box and came to focus side by side on a very sensitive photographic plate which fell when the gun trigger was pulled, thus causing the sunbeams to trace three fine lines on the plate. As the bullet in its flight eclipsed successively the thin sunbeams, little breaks were made in their records on the plate. These records were then measured on a dividing engine, and from the data so obtained the velocity, retardation, and finally the resistance were computed.

The resistance was found to obey no very simple law. It varies more rapidly than the square, less rapidly than the cube of the velocity. For speeds from 250 to 1,000 feet a second, it is closely exprest by the equation,

$$R = 0.000008v^2 + 0.000000049v^3,$$

in which R is the resistance in pounds per square foot and v the speed in feet per second. This coincides with the general formula,

$$R = \mathrm{a}v^2 + \mathrm{b}v^3,$$

derived by Colonel Duchemin from purely analytical considerations, taking into account the rarefaction in the rear of a projectile. Thus the law so earnestly maintained by him, early in this century, and controverted by nearly all later experimenters, seems to be corroborated by the measurements made in this research, as far as they go.

The preceding observations may be summarized as follows:

(1) The resistance of blunt bodies at low speeds is given by the equation,

$$R = \mathrm{a}v^2,$$

R being the resistance, v the wind-speed.

(2) The resistance formula for blunt bodies at speeds from 250 to 1,000 feet per second contains two terms, thus:

$$R = \mathrm{a}v^2 + \mathrm{b}v^3.$$

(3) The resistance of thin planes is exprest thus:

$$R = \mathrm{a}v^{1.85},$$

in which a is a function only of the length of the plane.

(4) The total resistanse of a fair shaped body at moderate speed is:

$$R = \mathrm{a}v^2 + \mathrm{b}v^{1.85}.$$

(5) The resistance of rods is proportional to their diameter, that of wires dimishes less rapidly than the diameter.

(6) The skin-friction of even surfaces is practically independent of the material composing them.

(7) The resistance of symmetrical spindles and wedges of easiest shape, as of simple planes gliding at the most efficient angle of flight, is roughly, one-half friction, one-half unbalanced pressure.

HYTHERS AND THE COMPARISON OF CLIMATES.

Under the above title we had the pleasure of publishing in the MONTHLY WEATHER REVIEW in June, 1907, page 267, a letter from Mr. W. F. Tyler of Shanghai that had been a long time delayed. At that time we had not read Mr. Tyler's recent memoir—"The psycho-physic aspect of climate. London, 1907,"[1] but were desirous to make known his exprest hope (MONTHLY WEATHER REVIEW, June, 1907, XXXV, p. 268) that someone would investigate the limiting conditions of temperature and humidity under which animal life can exist. By experimenting upon animals in confinement such a research can be pushed to the determination of the death point. So far as human life is concerned there are many occupations in which life continues under observable extremes of heat and cold, dryness and moisture, calm and winds. Those who will keep records of their sensations when employed in iron or steel works, or in gas works, and especially in the well-regulated furnace rooms of ocean steamships,—those on the other hand who labor in the sunshine and pure air of the Imperial Valley and Salton Sea or the Sahara Desert, and those who as aeronauts or mountaineers penetrate cold clouds, should be able to add considerably to the data that Mr. Tyler is collecting for study.

The Editor recalls vividly his own experience in going from the deck of a steamer down into the furnace room with the stokers; the temperatures then determined by him with the protected sling psychrometer were about as given by (1) and (2) in the table. Another experience in the hot, dry air of a room heated by a Russian furnace gave observations (3) and (4). In the warm dry air of sunny winter quarters in Washington, such readings as (5) and (6) were obtained.

Perhaps the most delightful conditions were those of (7), prevailing thru the night in a strong southeast trade wind on the summit of Telegraph Hill on the Island of Ascension in February, 1890, where we could sleep without protection in a wind whose temperature scarcely varied from those of (7).

TABLE 1.—*Indoor and outdoor humidities observed by Prof. C. Abbe.*

Locality.	Dry bulb.	Wet bulb.	Dew point.	Relative humidity.
Atlantic steamer:	°F.	°F.	°F	*Per cent.*
(1) In the free air	91	85	83	78
(2) In the furnace room	120	91	83	33
Russia:				
(3) In the free air	0	2	20	33
(4) Furnace-heated room	120	65	20	1
Washington, D. C.:				
(5) In the free air	33	30	25	70
(6) Warm, sunny room	80	54	26	12
Island of Ascension:				
(7) In the free air	66	65	64	95

Most of these seven different conditions are agreeable to the writer with a proper adjustment of the wind velocity, but the sensations produced are widely various: thus (7) is restful and relaxative; (1) is perfectly indolent; (2), (4), and (6) produce a restless, uneasy, creepy, cold sensation as the skin becomes dry and harsh, one must drink much water and can scarcely do enough muscular exercise to counteract the dryness and keep the skin moist by a rapid circulation of the blood; (3) and (5) stimulate to exhilaration and to excellent intellectual work.

The following conditions—

[1] See Monthly Weather Review of May, 1907, p. 227, column 2.

(8) Free air 55°, wet 50°, DP 45°, RH 73 per cent,

(9) Free air 60°, wet 52°, DP 45°, RH 68 per cent,

are admirable for outdoor exercise and the attendant intellectual stimulus, when the rapid circulation of the blood enables the brain to work rapidly, easily, smoothly, and with precision. One who works steadily for several hours in quiet until his food supply becomes low, the blood fills with effete matter faster than the purifying organs can eliminate it, and the circulation becomes feeble—will usually find himself growing apparently colder, and will require the temperature of the room to be raised from 50° to 60° and perhaps to 70° or 80°, *i. e.*, to temperatures that would have seemed very uncomfortable at the beginning of his work.

These experiences are worthy of record and study, they will on the one hand elucidate the needs of our human physiology and on the other hand help us to more clearly define the relation between natural climates and the evolution of the peculiarities of the races of mankind.

The great variety of climates offered by the stations of our Weather Bureau and the frequent interchanges of observers suggests to us that each make a list of the stations at which he has lived, the length of time in years and months and the impressions produced on him as to the influence of the respective seasons of the local climates.

This information may possible be condensed into tabular form and a few general conclusions be drawn from the experiences of so many men. Mr. Tyler reminds us that for uniformity's sake the influence of the climate should be recorded on a scale of 0 to 10 where 10 will represent the worst day, hot, damp, close, muggy, enervating, that the observer remembers to have experienced at any time; and 0 will represent an ideal summer day, warm, brisk, bright and bracing. In the first case no diminution of clothing makes the free air less uncomfortable and in the second case no increase is needed in order to make it more comfortable. Mr. Tyler recommends that the estimates relate especially to the sensation at the noon or mid-day hours, unless indeed the observer wishes to make a very complete record and determe the diurnal changes.

This is a subject that we earnestly commend to the attention of the experts in physiology and psychology who are considering appropriate researches in several of our best universities.—*C. A.*

THE RELATIVE HUMIDITY OF OUR HOUSES IN WINTER.

In connection with the above note on Hythers and Climates, it may be of interest to many readers to have an account of certain related observations carried out by Prof. R. DeC. Ward in Cambridge, Mass., eight or nine years ago.[1] His account and comments are given in slightly changed form here.

The observations.—The observations were made in the study of the observer by means of H. J. Green's Marvin sling-psychrometer, and extended over three weeks of November, 1899, from the 3d to the 23d. The hours of observation varied, but the number was from two to five daily. Each observation comprised a record of the readings of the wet and dry-bulb thermometers, the condition of the out-of-doors weather, the amount of ventilation by means of the window, the temperature of the air coming from the furnace, and the stage of the water in an evaporating pan placed inside the register of the room.

The study in which the observations were made was heated by hot air from an ordinary hot-air furnace provided with the usual small evaporating pan. Inside the delivering register stood a vessel holding a little more than half a liter of water.

[1] The results were first published in the Boston Medical and Surgical Journal, March 1, 1900; later revised and printed in The Journal of School Geography, I, 1902, pp. 310-317.

This vessel had to be filled about once a day, altho the rapidity of evaporation was found to depend so directly upon the amount of heat from the furnace that the time required to evaporate the water was very variable.

The observations have been summarised in the accompanying Table 1. In this table the values given for the outdoor elements have been taken from the Richard thermograph and hygrograph exposed at the Harvard College Observatory, and are the recorded readings for the hours corresponding to the times of the indoor observations. These means for the outside air are thus not the true means for the day, but they serve the purpose of the comparative observations here presented.

TABLE 1.—*Observations on indoors humidity, during November, 1899, by R. DeC. Ward.*

Date.	Number of observations.	Inside air.		Outside air.	
		Mean temperature.	Mean relative humidity.	Mean temperature.	Mean relative humidity.
		°	*Per cent.*	°	*Per cent.*
3	5	69	28	35	66
4	5	71	39	42	69
5	5	71	30	43	64
6	4	69	29	34	68
7	5	68	32	39	63
8	5	71	31	44	69
9	4	69	32	42	69
10	3	67	32	47	60
11	4	69	33	28	77
12	3	64	30	23	70
13	4	67	24	23	51
14	3	67	26	25	75
15	3	71	31	28	91
16	4	72	29	36	68
17	2	68	27	24	66
18	2	68	31	28	90
19	3	71	40	42	87
20	3	70	28	39	69
21	4	69	25	41	70
22	4	71	30	46	77
23	3	72	26	43	72
Means		69	30	36	71

Notes to the table.—The maximum relative humidity outdoors was recorded on November 4 at 8 a. m. It had rained during the night, the outside air was very damp, and an easterly wind was blowing. The window was partly open and but little heat was coming from the furnace. The outside humidity was 92 per cent and the conditions mentioned were clearly favorable for a high degree of relative humidity indoors. At noon of this day the indoor humidity was still high, 45 per cent, but the weather was then beginning to clear, the wind gradually veering to the northwest. The window was still open.

The lowest relative humidity was 21 per cent, recorded November 23 at 10 a. m. The outside weather was clear, with a moderate northwest wind, and the relative humidity was 68 per cent. The windows were shut and there was a good supply of heat from the furnace.

The maximum relative humidity for a whole day was 40 per cent recorded on November 19, a damp, rainy day, with overcast sky. The window was open thruout the day and there was moderate heat from the furnace. Outdoors the relative humidity averaged 37 per cent which was exceeded on only two other days.

The minimum humidity for a whole day was 24 per cent, recorded on November 13, a clear, cold day, with moderate to brisk northwest wind, and on the outside relative humidity of 51 per cent. The windows were shut most of the day and the temperature of the room averaged 67°. The outdoor humidity was the minimum for any whole day during the period of observation.

The mean relative humidity of the outside air for the whole period was 71 per cent or 40 per cent in excess of the mean for the indoors air.

Discussion.—The relative humidity in a room is clearly the resultant of severable variables, among which are the temperature and humidity outdoors, the amount of heat coming from the furnace, the amount of evaporation from the evaporating pans, the extent to which the room receives the outside air thru the open windows, etc.

It appears from the data that the relation between the relative humidity of the air outside and inside is fairly close, increasing relative humidity outside being closely followed by increasing relative humidity indoors, and vice versa. The weather conditions during the absolute maximum of 45 per cent, and the daily maximum of 40 per cent were, as has been seen, precisely such as would have led one to expect high humidity indoors. These same relations appear distinctly on many of the other days of the observations. Thus on November 4, a change of wind from southeast to northwest, accompanied by clearing weather, was closely followed by a decrease of 34 per cent in the outside relative humidity and of 6 per cent indoors. Again, on November 11, a change of the wind to the east with rain, brought a rise in relative humidity of 15 per cent outside and of 6 per cent indoors. The next day, November 12, was rainy, followed by a clearing day, with northwest wind, and the relative humidity fell steadily from 32 per cent at 8 a. m. to 30 per cent at noon, and to 28 per cent at 6 p. m., the decreasing humidity keeping pace with the decreasing cloudiness and increasing velocity of the dry northwest wind. Outside the relative humidity fell from 78 per cent at the first observation to 69 per cent at the second and 63 per cent at the third. The windows were closed at the time of all the above changes.

Indoors climate vs. *an arid climate.*—The following Table 2, presents the relative humidities at a number of localities and these when compared with the records within the study as just related, suggest some very interesting conclusions. They show clearly that the atmosphere of Professor Ward's study was drier than that of many desert regions, dry to the point of being dangerous to health as he shows. He finds that the strain which is put upon the body in the rapid readjustment required when we go from the high temperatures and desert aridity of our houses in winter, into a temperature 70° to 90° lower and a relative humidity of 70 to 100 per cent is a greater one than we ought to repeat day after day and many times a day.

TABLE 2.—*Low relative humidities in the United States.*

Station.	Mean annual.	Mean monthly minimum.
	Per cent.	*Per cent.*
Yuma, Ariz	42.9	34.7 in June.
Santa Fe, N. Mex	44.8	28.7 in June.
Pueblo Colo	46.2	37.6 in April.
Death Valley, Cal	23.0 for May to September, 1891.	

In the dry interior of the great Eurasian Continent we find the following relative humidities:

Southwestern Siberia and western Turkestan have a mean of 45 to 50 per cent in July. Yarkand, in eastern Turkestan, has a July mean of 47 per cent. In the arid region about the sea of Aral, Nukus has a June mean of 46 per cent and a 2 p. m. June mean of 19 per cent. Petro-Alexandrovsk, 1.5° west of Nukus, and in the desert, has a June mean of 34 per cent. Kasalinsk, latitude 45.8° north, longitude 61.2° east, has a July mean of 45 per cent. The air is still drier in the deserts near the equator. Ghadames, Tripoli, has 27 per cent in July, and 33 per cent in August. The Kufra Oasis has 27 per cent in August and a 3 p. m. August mean of 17 per cent. In the Punjab and northwestern India, Lahore has 31 per cent and Agra has 36 per cent in May.

It is generally acknowledged that the winter temperatures of our houses are too high, but the excessive dryness of the indoors air and consequent rapid evaporation from the skin combined make most of us uncomfortable unless the temperature is kept up to 70°, or higher. Were the relative humidity

of the house air higher, as it always is in the kitchens where steam is continually being sent into the air, then a temperature of 65° would be very comfortable. Such moisture can be introduced into the house air by increasing the evaporating area of the water-pans in the hot-air furnace or by placing similar pans over the super-heated steam coils of the steam-heated house.

Observations somewhat similar to the above were also made by Dr. H. J. Barnes[2] in his own office in Boston, and also in other buildings in Boston. By means of an apparatus of his own devising Doctor Barnes was able to maintain a mean relative humidity of 53 per cent in his own office. This device placed over the delivering register of the hot-air furnace evaporated on the average four and one-half quarts of water daily, and the resulting increased relative humidity kept the office comfortable at a temperature of 65°, while under the usual drier conditions the room must have a temperature of 70° or 71°.

TABLE 3.—*Dr. H. J. Barnes' table of relative humidities in various Boston buildings.*

Place and time.	Heated by—	Mean relative humidity.	
		Indoors.	Outdoors.
		Per cent.	*Per cent.*
City Hospital, 7 days, December, 1878	Indirect steam	29	71
Office of Dr. Barnes, 7 days, January, 1896	Hot-air furnace	27	73
Office of Dr. Ayer, 10 days, February, 1896	Indirect steam	36	70
Women's Hospital, 8 days, February, 1896	Indirect steam	24	71
City Hospital, 12 days, February and March, 1896	Indirect steam	38	74
Means		31	71

SCIENTIFIC BALLOONING AND WEATHER FORECASTS.[1]

By Dr. K. BAMLER, Essen. Translated by Prof. A. G. MCADIE.[2]

One of the chief problems of aerology is the improvement of the forecasts. Every prominent daily paper now publishes a weather bulletin based upon a synoptic weather map. In our country [Germany] the material for this map is collected by the German Hydrographic Office, or Seewarte, in Hamburg, and the forecasts are prepared by some proper central office. The data used by the Seewarte in preparing the weather map are from stations having nearly the same elevations. They give us a picture of the meteorological conditions at the time, as they existed at the bottom of the sea of air. Long experience enables us in many cases to determine what the ensuing weather conditions will be. But so long as we do not know the laws underlying the variations of the individual meteorological factors, so long will forecasting continue an uncertain science; and these laws can never be determined from observations made at the surface of the earth, be they ever so painstaking. We must make observations at greater elevations, but not on high mountains, for such are not wholly free from the influence of the ground. We must rise into the free air and observe there, and this is the province of aerology.

The scientific results of the instrumental observations made in the balloons sent up on the international dates of November, 1907, by the Lower Rhine Society for Aeronautics, show how valuable such ascensions are for forecasting. On November 6 the balloon "Bamler," with Ernst Schroeder of Essen as pilot and Engineer Mensing as observer, ascended from Mülheim and after four and one-half hours landed near Goor, in Holland. On the 7th of November the balloon "Elberfeld," with Professors Silomon and Laubert, ascended from Mülheim and after a trip of four hours landed in Wesel. Both ascensions aimed to reach the greatest possible height and make detailed temperature observations at all levels. Altho both pilots used up all of the 200 kilograms of ballast in their efforts to keep the balloons steadily ascending to a maximum altitude, yet an elevation of only 2,400 meters was attained. This apparently poor record is readily explained by the temperature distribution, as we shall see later.

On November 6, the temperature distribution was as follows: At the start, 10 a. m., a light fog prevailed near the ground and a temperature of 2° C. was recorded, and this gradually decreased up to a height of 600 meters. At this level the balloon was above the layer of haze and the temperature now rose steadily until a height of 1,500 meters was attained.

At the same time the difference between the readings of the dry and wet thermometers increased, indicating that the air became drier with increasing altitude. This is more apparent in the following table:

TABLE 1.—*Humidity observations in the "Bamler," November 6, 1907.*

Altitude of balloon.	t_d	t_w	$t_d - t_w$
Meters.	°C	°C	°C
Ground	2	1	1.0
640	4	1.2	2.8
940	5	2	3.0
1100	6.3	2.3	4.0
1300	8.0	3.	5.0
1450	8.4	1.1	7.3
1500	9.0		
1900	9±		4.0
2150	6.8		

At the 1,450 meter level was the driest air noted during the ascension, with a relative humidity of only 14 per cent. The highest temperature, 9° C., was reached at 1,500 meters, and this temperature continued practically up to 2,000 meters, but the relative humidity increased so that at 1,900 meters there was a depression of only 4° C. Above 2,000 meters the temperature fell slowly, and at 2,150 meters read 6.8° C. Values at greater elevations could not be taken, owing to difficulty in controlling the balloon. Practically similar temperatures were found during the descent, except that near the earth's surface, owing to sunshine, the temperature had risen to 5° C.

How, then, are we to explain this unusual distribution of temperature? Unusual because there should be a fall in temperature with elevation averaging 0.5° C. for each 100 meters. The decrease is easily understood, since the air is warmed chiefly by the heat radiated from the ground. On a normal day the lower air will be warmest, and with increasing elevation the temperature will continue to fall. But in this case the reverse condition existed. It happened that on the dates under discussion a wide-spread area of high pressure with weak gradients, prevailed. In such high-pressure areas the upper air sinks slowly, gradually coming under greater pressure and thus warming and drying as it descends. Under such conditions also we expect to find the highest temperature and lowest humidity close to the ground. But the active radiation fostered by these long, clear autumn nights directly opposes such a distribution of temperature, and the chilled lower air layers tend to form a more or less heavy blanket of fog near the ground. Such a temperature inversion as is shown in these observations, namely, 17° C. in 2,000 meters, is a frequent occurrence in the mountain regions during fall and winter. Indeed it is not unusual, in the upper Rhine section, to find a fog layer 200 to 300 meters in thickness and a temperature of 0° C., while from Sulzer Belchen, at an altitude of 1,400 meters, are reported temperatures of 8° C. to 10° C. and a fine, clear view of the distant Alps.

In what way, then, can we utilize these observations in forecasting the weather for the following day? The forecast issued by the Berlin Weather Bureau was: "Along the coast slowly rising temperature with cloudiness and some rain in

[2] See "The arid atmosphere of our houses in winter" in the Trans. Amer. Public Health Assoc., 1898.

[1] Translated from Illust. Aeron. Mitth. 12ᵗᵉ Jahrgang, 1908, p. 29-33.

[2] The translator wishes to acknowledge the kind assistance of Mr. Louis Ludholtz and Dr. C. Abbe, jr., in preparing this translation.

the northeast; it will continue generally dry in the interior." Based upon our experiences, we would have said about as follows:

As a movement of the prevailing high pressure area is not expected, dry still weather, and during the mid-day hours free from cloudiness, will continue for several days. The temperatures will reach noticeably high values with very low humidities about mid-day. The proof of the correctness of these views can be seen from the weather conditions. If these continue, then the dynamic heating of the air must proceed from below, while during the night, on account of the rapid cooling of the earth's surface, the heat will indeed be dissipated, but during the afternoon hours a direct foehn-like heating will be shown.

The observations of November 7 give just such a chart as we would expect. At 11 a. m. there was a surface temperature of 11° C. and a wet-bulb difference of 3.5° C.; at 220 meters the temperature was 7° C., and at 480 meters it was 5.4° C. Above the fog layer, at 600 meters, the temperature was 9° C. with 6° C. difference. On the preceding day the temperature of 9° C. was first noted at a height of 1,500 meters; therefore the warm, dry air settled about 900 meters during the course of twenty-four hours. In consequence of this settling, the overlying layers were somewhat heated, so that the highest temperature, 11° C., was noted at a height of 740 meters, and the temperature continued at this figure up to 1,100 meters. Above this level, as during the preceding day at 900 meters, began the regular decrease in temperature and humidity, so that at 2,400 meters the temperature was only 1.0° C. with a wet-bulb difference of 5° C. The pressure distribution already described persisted until November 10, and each day during this period the mid-day temperatures exceeded 15° C.

It is also interesting to note the behavior of the balloon under these temperature conditions. Usually if a weight of ballast equal to 1 per cent of the total weight of a balloon be expended, the balloon will rise about 80 meters, provided no other factors are involved. The balloons "Bamler" and "Elberfeld" each weighed about 1,000 kilograms as the outthrow of ballast began. At the beginning 1 per cent of this weight would equal 10 kilograms; but during the course of the ascension, after say 50 kilograms of ballast had been used, 1 per cent of the remaining weight would equal only 9.5 kilograms, and after 100 kilograms had been used 1 per cent would equal only 9 kilograms. To make the balloon rise 200 kilograms of ballast had to be expended, and according to theory the balloon should have then ascended 1,800 meters. In both cases the expenditure of ballast began above the fog layer, i. e., at about 700 meters. Therefore the maximum height reached should have been $700^m + 1{,}800^m = 2{,}500$ meters. As a matter of fact the height reached was only 2,400 meters. In a normal distribution of temperature, i. e., with constantly decreasing temperature, and with favorable insolation, the balloon should have reached a much greater height, for the sun rapidly warms the envelop and its contained gas, owing to the clarity of the upper air. Temperature differences as great as 30° C. between the contained gas and the surrounding air have been observed. Every degree of such a temperature difference raises a balloon filled with illuminating gas about 30 meters. Assuming that our contained gas was 20° warmer than the surrounding air, the balloon should have ascended 600 meters in consequence, making the maximum height 3,100 meters—an elevation that is often reached during similar ascensions. In our case, however, the cold gas was always advancing into warmer air layers [because of the inverted temperature gradient] and it was necessary, therefore, to use more ballast in the ascension than usually would have been required. Hence the moderate heights reached.

THE KITE STATION ON LAKE CONSTANCE.

By ERNST KLEINSCHMIDT, Ph. D., Director. Dated Friedrichshafen, September 23, 1908. Translated by C. F. Talman.

The kite station on Lake Constance has been in regular operation since April 1 of this year. Its task is to make daily observations, when practicable, of the atmospheric conditions over Lake Constance. The principal object is to measure the temperature, humidity, wind direction, and wind velocity at different altitudes in the air. For this purpose suitably constructed registering apparatus must be lifted by kites or captive balloons; free balloons would be too costly for daily use, and besides too much time would be required to make available the records obtained by them.

Special methods of investigation are required on account of the wind conditions that prevail in the interior of Europe. The wind is generally too weak for kites, but, on the other hand, it is often too strong for captive balloons, the latter being forced downward by strong winds. This difficulty can be overcome if the reel holding the steel wire used for the flights can be readily moved about, as, for example, when it is mounted aboard a swift boat having a sufficiently large body of water to maneuver upon. In flying kites, if the wind is too weak the vessel runs against the wind, thus strengthening its effect. In sounding with captive balloons the vessel moves in such a manner as to keep the balloon directly overhead. In the latter case we can deduce the direction and velocity of the wind at each altitude from the course and speed of the vessel. A boat offers the further advantage that when the wind is so strong as to threaten the destruction of the kites we can lessen its effect by running *with* it.

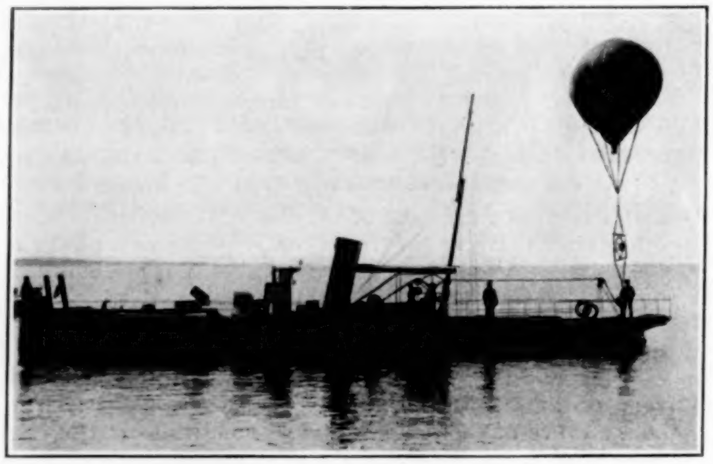

FIG. 1.—The German kite-boat *Gna*, Lake Constance.

FIG. 2.—The German kite-boat station, Friederichshafen, Lake Constance.

The work of the station is carried on as follows:

Every day, before the flights are begun, the wind conditions as high up as possible are determined, either from the movement of the clouds or, preferably, by means of pilot balloons. We thus decide whether we had better send up a kite or a captive balloon; taking into account the fact that the boat must be run as short a distance as practicable, in order to economize coal. We also decide from what point on the lake the flight should be begun so as to have as much room as possible for the vessel to run in and not be obliged to abandon the flight prematurely on account of nearness to the shore. During the summer months we have, as a rule, used captive balloons of rubber-coated cotton or silk, and having a capacity of 30 to 50 cubic meters. As they have a vertical ascensional velocity of about 3 meters per second the ventilation thus produced fully suffices to prevent the effects of solar radiation. In many cases, however, a small electric ventilator is sent up with the apparatus. In winter we shall more often use kites of the Marvin and Hargrave types, having 5 to 7 square meters lifting surface. Our captive balloons have attained altitudes as great as 4,000 meters, but with kites we have not yet gone higher than about 3,000 meters.

The results of the ascents are promptly transcribed and telegraphed to the meteorological central stations of southern Germany (Strassburg, Karlsruhe, Stuttgart, and Munich), the Deutsche Seewarte at Hamburg, the Lindenberg aeronautical observatory, and several of the Public Weather Service centers in northern Germany. Our telegraphic reports have generally been early enough to use in making the weather forecast issued between 10 and 11 a. m.

The station owes its existence to the efforts of Professor Hergesell, who as early as 1901, in collaboration with Count Zeppelin, flew kites—without instruments, however—from a small motor boat on this lake. The station was erected and has been maintained by contributions from the Imperial Government and the governments of the four South German States, Bavaria, Württemberg, Baden, and Alsace-Lorraine. It is located at Friedrichshafen, in Württemberg, and is under the administration of Württemberg. The station building, see fig. 2, which includes workshops and the necessary offices, stands on the harbor front, close to the anchorage of the kite-boat. The latter is of the torpedo-boat type, is 27 meters long, 3.4 meters beam, and has an engine of about 350 horsepower. It has a maximum speed of 19 knots. The reel is driven by an electric motor. The vessel was especially designed for kite and balloon flights, was built in 1907 at the Schichau yards, in Elbing, and cost 72,000 marks, or $18,000. It is named *Gna*—after one of the messengers of the gods in the northern mythology.

THE REFLECTING POWER OF CLOUDS.

The following article is compiled from the note of May 27, 1908, recently distributed by Messrs. C. G. Abbott and F. E. Fowle, jr., from the Smithsonian Astrophysical Observatory at Washington, D. C.—*C. A.*

The diffused reflection and radiations from fog and cloud and even dusty air, are of appreciable importance in dynamic meteorology and even climatology. They are so analogous to those from solid matt surfaces that the formulas given by Abbott and Fowle must closely represent the natural intensity when the incident light is homogeneous and the cloud particles are much larger than the incident wave lengths.

A perfect matt surface may be defined as one which reflects diffusely the whole of the radiation incident upon it, in such a manner that equal solid angles observed on such a surface contribute equal amounts of reflected radiation, independent of the nadir distance.

Let AB, in fig. 1, represent an infinitely extensive plane of perfectly matt surface; let CD represent an infinitely extensive plane parallel to the plane AB. Let a, b, c, d, be four equal areas situated so that ac is normal to AB and the angles dac and bca are equal. Let them be represented by the symbol i. Let the zenith distance of the sun be Z and let K be the amount of radiation it sends to an area equal to a situated at right angles to the solar beam. Then the amount of solar radiation on a, or b, is $K\cos Z$.

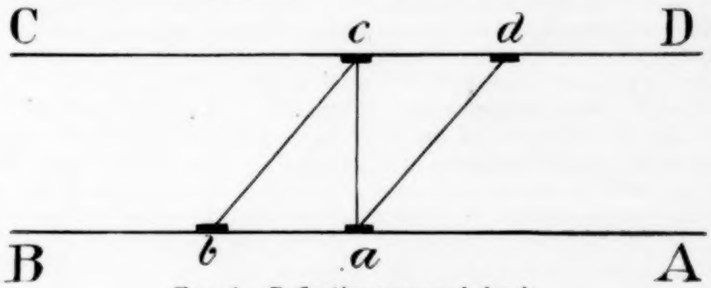

FIG. 1.—Reflecting power of clouds.

By diffuse reflection the area a sends the same amount of radiation to the area d that b sends to c. A ring drawn in the plane CD about c as a center, with a radius equal to cd would contain as many areas equal to d as a similar ring drawn about a as a center in the plane AB. For each such area situated in the upper ring in a given position with regard to a as a center in the plane AB. For each such area situated in the upper ring in a given position with regard to a, there is an area on the lower ring to which c bears exactly the same relation of position. From this it follows that the sum of all the radiation received by c is equal to the sum of all the radiation diffusely reflected by a; and this, since the surface AB is a perfect matt surface, is equal to the total amount of solar which falls on a.

Let Q be the amount of diffusely reflected radiation which a surface of the area c would receive if directed toward an area of the surface AB subtending a solid angle equal to that of the sun. Let α be the angular semidiameter of the sun. Then the angular area of the sun is $\pi\alpha^2$.

For an element of angular area upon the plane AB at nadir distance i and azimuth A the expression is $\sin i \,.\, \mathrm{d}i \,.\, \mathrm{d}A$. Such an element will reflect upon the horizontal area c the amount of radiation

$$\frac{Q \sin i \,.\, \cos i \,.\, \mathrm{d}i \,.\, \mathrm{d}A}{\pi\alpha^2}.$$

Hence, the total reflection upon c is

$$\frac{4Q}{\pi\alpha^2}\int_0^{\frac{\pi}{2}}\int_0^{\frac{\pi}{2}} \sin i \,.\, \cos i \,.\, \mathrm{d}i \,.\, \mathrm{d}A = \frac{Q}{\alpha^2}$$

Hence,

$$\frac{Q}{\alpha^2} = K \cos Z$$

and

$$Q = K\alpha^2 \cos Z.$$

Then, neglecting the difference in height above sea level between the cloud and the observer, every area of a perfectly matt cloud subtending a solid angle equal to that of the sun, would reflect to the measuring instrument an amount of radiation $\alpha^2\cos Z$ times the amount of radiation received directly from the sun, provided both the direct and the reflected beams were observed at normal incidence. On August 22, 1906, α^2 was 0.0000206.

But an allowance must be made for the loss of intensity of the beam in its course from the level of the observer to the cloud and thence back to the level of the observer, and for the considerable difference of level of the cloud of August 22,

1906, and the observing station. In fact this correction would be large. While no accurate measurements were made, it is thought that the difference of level on that date was about 1,500 feet. The air pressure corresponding to this difference of level would be about 0.055 of the barometric pressure above Mount Wilson. According to the pyrheliometry of August 21 and 23, 1906, we may estimate the general atmospheric transmission coefficient for August 22 as 0.90 for vertical transmission thru all the air above Mount Wilson. Hence, for vertical transmission thru the layer in question the transmission may be estimated at $(0.90)^{0.055}=0.994$.

For the very large angles of zenith distance Z, and nadir distance i, the paths of the beam in this layer ought not to be taken as simply proportional to $(\sec Z + \sec i)$, and we shall rather use the air-mass values of Laplace as given by Radau in his "Actinometrie," altho these are also of doubtful application in the present instance. Let us call the air-mass $\varphi(Z)+\varphi(i)$, where φ is a function to be taken from the above sources. Then the values of reflection given for August 22, 1906, in Table 25 of the Annals, are to be increased in the ratio

$$\frac{1}{0.994^{[\varphi(Z)+\varphi(i)]}}$$

to allow for the difference of level. No correction of this kind is thought necessary for the values of September 13, 1906, as the cloud was practically at the level of the observer.

An entirely new set of apparatus for measuring the reflecting power of clouds is now in place at Mount Wilson, and we hope to obtain a great many additional measurements there this year. We therefore refrain from computing at present a new value of cloud reflection and of the albedo of the earth from the observations of 1906.

EARLY METEOROLOGY AT HARVARD COLLEGE. 2.

By B. M. VARNEY, Assistant in Meteorology. Dated Cambridge, Mass., September 10, 1908.

In a recent article[1] on the early history of meteorology at Harvard College the writer mentioned the announcement of lectures by Isaac Greenwood, the first Hollis Professor of Mathematics and Natural Philosophy. While the strictly meteorological subjects comprise but a small part of this announcement, and therefore presumably of the lectures, it is probably one of the oldest extant records of scientific lectures in this country and thus has considerable historical interest. A few pertinent historical notes which the writer has been able to gather follow the "Syllabus." The absence of a full text of the lectures and of contemporaneous accounts of them renders a detailed study impossible.

A

Course of Philosophical Lectures,

with a great Variety of

Curious Experiments,

Illustrating and *Confirming*

Sir ISAAC NEWTON'S *Laws*

OF

MATTER AND MOTION.

By ISAAC GREENWOOD, *A. M., &c.*

ARTICLE I.

Of the FUNDAMENTAL PRINCIPLES *of* MATTER

Where the essential Properties *of* Space *and* natural Bodies, *are shewn, in a great variety of* Experiments: *And the* NEWTONIAN LAWS of Matter *demonstrated.*

I. *Of the* ESSENTIAL PROPERTIES *of Space and* natural Bodies.

[1] See Monthly Weather Review, May, 1908, XXXVI, p. 140.

LECTURE I.

OF EXTENSION—The Manner of *Conceiving* and the *real Proof* of a *Vacuum*, by several *curious Experiments*—The *inconceivable Divisibility* of the Parts of Matter, shewn in *natural* and *artificial Instances*, by a Sett of *microscopical Observations*, and prov'd by Dr. *Neiuwentyt's Experiment* of the *Division* of Water, by the *Ælopile;* on which *Principle* the *Operation* of the celebrated *Engine to raise Water by Fire*, will be explained in a very large *Cutt* thereof.

Lecture 2. Of the SOLIDITY and POROSITY of *natural Bodies* in many *useful Experiments* and *critical Remarks*; where particular Notice will be taken of the *Alterations* they are subject to by *Heat* and *Cold, Dryness* and *Humidity, Weight* and *Levity*, in many *curious Experiments*. And of the STRUCTURE and FORMS of *natural Bodies,*—their *inward Disposition,—external Configuration*, with a Variety of *Experiments* relating to the *Changes* of their *Forms* on many Considerations.

II. *Of the* NEWTONIAN LAWS *of* MATTER.

Lecture 3. Of the *Fundamental* LAW; viz. GRAVITY or GRAVITATION, (where all its *Properties* will be *very particularly* illustrated and confirmed) together with the other two *General Laws*; viz. the COHÆSION and REPULSION existing between the *minute Parts* of *Matter*, in a great Variety of *Experiments*.

Lecture 4. Of the SPECIAL LAWS of MATTER; viz. MAGNETISM and ELECTRICITY; where their *surprising* and most curious *Phænomena* are shewn in a Sett of very useful and *delightful Experiments* of *late Invention*.

ARTICLE II.

Of the FUNDAMENTAL PRINCIPLES *of* MOTION.

I. *The* Principals *of* MECHANICS.

Lecture 5. *Explanations* of *necessary Terms*, with many *Experiments* relating to the *Places* of the *mechannic Centers* of Bodies, their *Velocities, Quantities of Matter*, and *Momenta* of *Motion*.—The *Fundamental Propositions* relating thereunto, proved on proper *Machines*—*Experiments* about the *falling, sliding*, and *rolling* of *Natural* Bodies, &c., very *curious*; the *Solution* of several entertaining *Problems*, relating to *Animal Motion* and *Action*; with a Conclusion concerning the Explanation of the *Motion* of the *Astronomical Bodies* on these *Principles*.

Lecture 6. A full *Explanation* with many *Experiments*, on the *Five Mechanical Powers* or *Simple Machines*; viz. the *several Kinds* of *Ballances, Levers, Pullies, Wheels* and *Axles, Wedges* or *Screws*; of *Compound Machines*; and the *Invention* and *Use* of many *useful* and *curious Engines*.

II. *Of the* NEWTONIAN STATICS.

Lecture 7. Of *absolute and relative motion.*

Sir ISAAC NEWTON'S

1. *Law of Motion*, viz. *That all Bodies continue in the State of Motion or Rest, uniformly, in a right Line, except so much as that State is Chang'd by Forces impress'd*; with many *Examples* and *Experiments*; Of the great Use thereof in the *Motion of Bodies* proceeding from *single* and *Compound Impulses*. Of the *Phænomena* of *Diagonal Motion* and *oblique Powers*.

2. *Law of* Motion, viz. *That the Change of Motion is always proportional to the moving Force impress'd; and is always made in the right Line in which that Force is impress'd.* Of the *Phænomena* of *Accelerated* and *Retarded Motion*.

Of Projectile Motions.

Lecture 8. Of *oblique Descents*; where all the curious *Experiments* and *Observations* relating to *Pendulums* and their *Uses*, will be made. Of *Circular* and *Elliptical Motion*, with many *Experiments*. Dr. *Desagulier's* celebrated *Experi-*

ment, proving the *oblate Figure* of the *Earth*, from its *Diurnal Motion*.

Lecture 9. 3d *Law of* Motion, viz. *That the Actions and Reactions of Bodies upon one another are equal and in contrary Directions*. (1) Of the various *Phænomena* consequent upon the *Congress* or *Percussion* of *Natural Bodies*. (2) Of the *Doctrine* of Elasticity; where will be performed many curious Experiments concerning *Elastic Substances*: With an Application of the *Principles*, thence deduced, to explain the *Nature* of *Sound* and the *Theory* of *Music*; particularly of the Experiments of the *Division* of the *Monochord* and the Proportions of the Diameters of *Harmonic Chords* to produce any *Musical Notes*—of the *Scale of Music*—Effects of *Music* on *Natural Bodies*—of the Echo &c.

ARTICLE III.

Of the TRUE CAUSES of the PRINCIPLE PHÆNOMENA *in Nature, by Means* of the *Newtonian Laws* of MATTER and MOTION.

Lecture 10. (1) *A View of the World around us subject to these Laws* shewn on very good *Schemes* and *Instruments*; which [with?] an Account of Mr. *Professor Bradley's* new *discovered Motion* of the *Fixt Stars*.

(2) An *Enumeration* of the *Phænomena* in the SOLAR SYSTEM—*Effect* of Sir ISAAC NEWTON'S *Laws* of GRAVITATION, with his *Account* thereof.

Concerning which, *several curious Experiments* illustrating the *Nature* and *Reason* of the *Planetary* and *Cometary* Motions, the *Alterations* they are subject to, their *mutual Actions* &c., will be performed.

Lectures 11, 12. (3) *Of the Effects of* GRAVITATION, as to the *Earth*, in particular.

Of the *Fundamental Principles* with many Experiments relating to FLUIDS, HYDROSTATICAL and PNEUMATICAL.

Of the *Action* of the *Sun* and *Moon* upon the *Atmosphere*, and *Bodies* contained therein.

Of the *Action* of the *Sun* and Moon on the *Oceans* and *Seas*; *where* the NEWTONIAN *Doctrine of Tides* will be particularly illustrated and confirmed by Means of several proper *Machines* and *Schemes*.

Experiments of the Pendulous *Motion* of Waves.

Of the CONSTANT CURRENT of all *Oceans*, Eastward—a *Discovery* never yet made *public* with its true *Cause* and *Effects*.

(4) *An Enumeration* of the *principal Phænomena,—Effects* of SIR ISAAC NEWTON'S other *Laws of Nature*, viz., COHÆSION, REPULSION, MAGNETISM and ELECTRICITY.

Where, with many other *Curiosities*, a *particular Consideration* will be taken of Dr. *Desaguliers* late *Theory* of the *Rise* of *Vapours* and *Formation* of *Clouds*, and *Meteors*, with his Experiments concerning them.—Dr. *Halley's* Account of the *Aurora Borealis* with his *Experiments*—Mr. *Gray's* new *Discoveries* as to *Electricity* &c.

N. B. Some *Entertaining Things* will be shewn, during the Course, with the *Magic Lanthorn, Camera Obscura*, good *Telliscopes, Microscopes*, &c. that fall not properly under any of the foregoing Heads.

The *Apparatus* is compleat for the *Experiments*, and will be *inlarged* with new *Machines* and *Models* of some *curious Engines*, lately invented, if there be a *full Course*.

CONDITIONS.

Every *Subscriber* to pay *Four Pounds, One* at the Time of *Subscription* and the *Remainder* on the 3*d* and 6*th Day* of the *Course*.

This Course to begin on ——— Instant, at —— o'Clock in the —— noon, and to be continued afterwards on what Days and Hours best suits the Company.

Isaac Greenwood was born in May, 1702, probably at Boston, Mass., since his father was a resident of that city. He was graduated with the Harvard class of 1721, studied for the ministry, and visited England, where, as we are told, he "began to preach in London with some approbation." He became a pupil of Desaguliers, and the pursuit of scientific studies resulted in his leaving the pulpit. Eventually he persuaded Thomas Hollis, a London merchant, to establish a science professorship at Harvard College, and he was appointed the first occupant of the chair.

According to the "Rules and Orders" stipulated by Hollis, the duties of the holder of this professorship, outside of his regular college lectures, were:

> 3. That the Professor shall read once a week and when ever the Corporation with the approbation of the Overseers shall require it twice a week (Times of vacation excepted) publickly in the Hall to all students that will attend on such topics relating to the Science of the Mathematics Natural or Experimental Philosophy as he shall judge most necessary & usefull but always distinct or different from his private lectures.

It still remains uncertain whether or not these lectures delivered publicly to students were those announced in the Syllabus reproduced above. They were, however, "different from his private lectures." The statement made in my previous paper, regarding this, may therefore need qualification.

On February 5, 1727, the Corporation of Harvard College

> Voted: yt Coll. Hutchinson & Mr. Sever be desired in the name of ye corporation, to wait on his Honr ye Lieutenant Governour, to know when it will suit his Honr to afford his Presence at ye Installment of Mr. Isaac Greenwood Hollisian Professor of ye Mathematicks & to appoint a meeting of ye Honble & Revnd overseers at ye College for yt purpose.

His Honor lost no time, as the following press-notice[2] shows:

> Mr. Isaac Greenwood was inaugurated at the College Hall in Cambridge into the office of the Professor of Mathematicks and Natural and Experimental Philosophy lately founded by that great and living Benefactor to the Society, Mr. Thomas Hollis of London, merchant. And we hear Mr. Greenwood gave his first public lecture at the College Hall on Wednesday last, Feb. 7.

The institution of a professorship in natural science at a college where the classics had from the first formed a major part of the curriculum, probably caused more stir in Boston and Cambridge than the quotation implies.

It was, of course, almost inevitable that Professor Greenwood's lectures should in general follow the order of treatment of the various mechanical powers and natural phenomena as given in the Course of Experimental Philosophy of his great English teacher, who in turn had his inspiration from Sir Isaac Newton. Desaguliers (born of French parents in 1683, at La Rochelle, France) was elected a member of the Royal Society in 1714 (Isaac Newton was then president), and was invited to become its demonstrator and curator. He is said to have been the first to deliver lectures on scientific subjects to the general public—a fact which renders it more than likely that Greenwood's lectures were the first on similar subjects in the United States. Desaguliers' lectures were attended by the most learned men of his day, and were made interesting by skilful experiments. He contributed voluminously to the Transactions of the Royal Society.[3]

It is probable that Greenwood made use of Desaguliers's teachings and experiments further than simply to discuss his theory of the rise of vapors and formation of clouds. On this theory, definitely meteorological in its interest to us, its propounder writes as follows:[4]

> Now may not this phaenomenon of the rise of vapors depend upon electricity in the following manner?
>
> The air which flows at the top of the surface of the waters is electrical, and so much the more as the weather is hotter. Now in the same man-

[2] New England Weekly Journal, February 13, 1727.

[3] A brief account of his life, and a full list of his works is contained in the "Dictionary of National Biography."

[4] Phil. Trans. Roy. Soc., Vol. XLII, p. 142.

ner as small particles of water jump toward the electric tube, may not those particles jump toward the particles of air, which have much more specific gravity than very small particles of water, and adhere to them? Then the air in motion having carried off the particles of water, and driving them away as soon as it has made them electrical, they repel one another, and also the particles of air. This is the reason that a cubic inch of vapour is lighter than a cubic inch of air; which would not happen if the particles of vapour were only carried off in the interstices of air, because then a cubic inch of air, loaded with vapour, would be made specifically heavier than dry air; which is contrary to experiments, which show us by the barometer, that air which is moist, or full of vapours, is always lighter than dry air."

In the Course of Experimental Philosophy just quoted, Desaguliers pays much attention to the barometer, especially to its construction according to various patterns, and gives at considerable length the substance of Halley's "Discourse Upon the Reasons of the Rise and Fall of the Mercury in Fair and Foul Weather."[5] To one interested in the history of the barometer, the thermometer, and the hygrometer, there are many pages of fascinating reading in Desaguliers' book.[6]

The Doctor Halley mentioned by Greenwood in connection with his twelfth lecture, on the aurora, was the astronomer Edmund Halley. Greenwood probably referred to his Account of an Aurora Borealis seen at London, November 10, 1719[7]. Altho Halley's fame rests chiefly on his work in astronomy and mathematics, he wrote much on purely meteorological subjects. The following list, tho possibly not directly connected with Professor Greenwood's lectures, is interesting for the light it throws on early meteorology in England. Maty's Index to the Philosophical Transactions of the Royal Society gives the volume and page for each contribution.

A discourse of the rule of the height of the mercury in the barometer.
An historical account of the trade-winds and monsoons (published in 1686).
An estimate of the quantity of vapour raised out of the sea by the warmth of the sun.
An account of several experiments made to examine the nature of the expansion and contraction of fluids by heat and cold, in order to ascertain the divisions of the thermometer, and to make that instrument in all places, without adjusting it by a standard.
On the proportional heat of the sun in all latitudes, with the method of collecting the same.
An account of the evaporation of water, as it was experimented in Gresham College, in 1693, with some observations thereon.
An account of the Torricellian experiment, tried on the top of Snowdon-Hill, and the success of it.
An account of Dr. R. Hook's invention of the marine barometer, with its description and uses.

Doctor Neiuwentyt, or Neiuwendijdt, named in connection with the Aeolopile (Lecture I), was a Dutch philosopher, born in August, 1654, and died in May, 1718. He was rather a famous physician in his day.

Mr. Greenwood's tenure of the Hollis professorship came to an early end in 1738, and he died prematurely seven years later at Charleston, S. C. His successor was Prof. John Winthrop.

JOHN WINTHROP'S LECTURES.

While Greenwood's Syllabus contains the first printed announcement of lectures at Harvard College, Winthrop's Summary of a Course of Experimental and Philosophical Lectures is the earliest known record of the text of such lectures, and probably the first of scientific lectures in this country. Only a small section of them dealt with meteorology, strictly so called. It has seemed best to bring this section out of the seclusion of the original manuscripts and to present it in full to the meteorological public. The old spelling as given in the manuscripts of the "Summary" and of the "Meteorologic Diary" has not been retained here.

Lecture 21st. April 26. [*1746.*]

We have already considered incompressible fluids, we now come to speak of compressible ones; tho air be the only one we know of. This air is a fluid lighter than any one we know of; and it encompasses the whole earth. When considered altogether it is called the atmosphere. Air has gravity, for by its pressure it will sustain water in a tube 35 feet and mercury 30 inches. The Torricellian experiment (so called from its inventor) is made with a tube sealed at one end and filled with mercury; then inverted into a basin of the same, it remains suspended at a height of 30 inches. This is called a barometer, and serves not only to show—

1. That there is a pressure of the air—but
2. To show the quantity of that pressure—and
3. To show that the pressure is different at different times—and also
4. To measure the heights of mountains and the depths of mines—and
5. This barometer rises in serene, fine and pleasant weather, and falls in foul and is lowest in stormy;

It is highest when the wind is in the northern board and the greatest variation is in winter and vice versa, all which arises from the different pressure of the air,—The pressure of the air on every square inch is = to 15 weight for a cubic inch of mercury weighs about 1/2 a pound: and by this computation is the whole atmosphere = in weight to a globe of lead of 60 miles diameter. And the pressure of it on a human body 30,000 pounds by the same computation. The greatest variation of the barometer is 3 inches, from 28 to 31. But in this country the greatest is 2 inches and 1/2 or from 28 3/4 to 30 3/4.—Now tho the mercury does not press the bottom of the tube it weighs as much as if it did; for its action against the side of the tube is horizontal, but the weight of the air sustained by the tube being equiponderate to the column of mercury in the tube; you in effect weigh only the atmosphere and tube instead of the mercury and tube. The air is elastic and perhaps more so than any other body whatsoever; for putting a bladder into the air pump 1/2 blown, the air in it expands and swells the bladder to the utmost extent; which was proved experimentally.

Near the end of the twenty-fifth lecture we find this:

The heat of the air is measured by a thermometer as gravity is by the barometer. Thermometers are of different kinds; as of air which forces water up into a tube by its elasticity, but it will never answer the end, because it's a barometer and thermometer too. They have till lately been made of spirits of wine; but those made of mercury are esteemed the best because they are most easily affected. There are some made of oil. Sir Isaac [Newton] made one of linseed oil and by this means measured the degree of heat in melted metals; the moisture and drought of the air is measured by an hygrometer which is made just as one fancies, but the most common are those made of a cord and a weight at the end of it. Some are made with cords and an index that turns with it.

At the close of the last lecture, the thirty-third, is written this:

This course of experimental and philosophical lectures, was concluded on the 16. of June 1746, by Mr. John Winthrop, Hollisian Professor of the mathematics, natural and experimental philosophy at Harvard College.

JOHN WINTHROP'S OBSERVATIONS.

Turning now from his public to his private meteorological work we find that Professor Winthrop was evidently a keen observer of the weather, aside from the mere taking of observations; and was interested in giving to the public, accounts of noteworthy meteorological events. Of these accounts only two appear to have been preserved. The following letter[8] tho unsigned, was undoubtedly written by Professor Winthrop, inasmuch as the temperatures given appear under their proper dates, in his Meteorologic Diary.

Cambridge, January 30, 1765.

Messirs Drapers,

As the weather of late has been extremely cold, some of your readers may probably be gratified with an account of the degree of it, as estimated by one of Fahrenheit's thermometers.

On the 9th instant, at	IX 1/4 M. it was	5
27th	VIII 3/4	4
28th	IX	9
29th	VIII 1/4	8

By this thermometer, there have been but four colder mornings than the 27th since the year 1708. The coldest of all was on the 12th of January 1752 at VIII M; when the mercury was 1/2 a degree below the point marked 0. On January 22, 1754, at VII 3/4 M, it was 3 degrees above 0. On January 18, 1757, at IX 1/2 M, it was 2 1/2 d. and on December 24, 1761, at IX 1/4 M, it was but 1 d. above 0.

Such a degree of cold, however severely felt by us, and sufficient to congeal our rivers and bays, is as nothing to what has been observed in other parts of the world. Travellers inform us that in Siberia, at the

[5] Original in Phil. Trans. Roy. Soc., Vol. XLII, p. 187.
[6] Barometer, p. 262–280, 303–306; Thermometer, p. 289–298; Hygrometers or "Notiometers," p. 298–302.
[7] Phil. Trans. Roy. Soc. Vol. XXX, p. 1099.
[8] Massachussetts Gazette, January 31, 1765.

end of June the earth has been thawed only to the depth of 3 feet, and below this has been found frozen to a great depth. 'Tis said, that in the summer of the years 1685 and 1686, in digging a well they got to a depth of 91 feet, and found the earth frozen hard all the way. And the cold has sometimes been so great, that with the help of freezing mixtures they have been able to fix mercury itself.

Your's, &c.

In the Proceedings of the Royal Society, Vol. LII, pt. 1, p. 6, appears "An account of a meteor seen in New England, and of a whirlwind felt in that country, July 10, 1760," contributed by Professor Winthrop. It deals first with a meteor that fell in southern Massachusetts, "by which the southern parts of the province were greatly alarmed," and then with the tornado. The account of this latter is very detailed, particularly as to the damage done. A careful description of the positions occupied by uprooted objects after the passage of the storm, leads the reader to expect an explanation of the cause of the whirl, none is given, however, and Winthrop closes his article thus:

It appears to me so difficult to assign a cause adequate to these effects, to show by what means a small body of air could be put into a circular motion, so excessively rapid as this must have been, that I dare not venture any conjectures about it.

The desultory accounts and observations above mentioned sink into insignificance when one opens the manuscript pages of Professor Winthrop's Meteorologic Observations, or, as he sometimes wrote it, Meteorologic Diary. These observations occupy three quarto volumes, each about 1½ inches thick. They cover in all no less than thirty-six years in an all but unbroken series, from December 11, 1742, to December 31, 1778. The "chasms," as he called them, aggregate barely two months of the entire time. This remarkable record, while by no means the first of its kind in this country and while possibly somewhat less accurate, because of faulty exposure of the instruments, than that of Doctor Lining at Charleston, S. C.,[9] has the distinction of being, by seventeen years, the longest continuous record kept by one person prior to 1800. Winthrop's own account[10] of his instruments, their exposure, the tables of observations, etc., as found at the end of the first year's record, is here given, nearly in full. It shows him to have been a careful scientist, tho, as appears from the text, he did not venture into the field of speculation. Meteorology in his day was still largely a matter of tabulation.

The [foregoing] diary is divided into 5 columns. The 1st shows the day and hour of the observation; the morning hours or those from midnight to noon being marked M; and the evening hours or those from noon to midnight being marked E.

The 2d column contains the height of the barometer in English inches and decimals. . . . I made use of a common or open barometer which I filled and inverted very carefully so as to clear it of air as effectually as I could. The diameter of the bore of my tube is .27 of an inch and the diameter of the cistern in which it is immersed is 3 inches. . . .

My thermometer was of Mr. Hawksbee's make, filled with spirits of wine. The scale is divided into 100 equal parts beginning from a certain point above marked 0 and the 100th degree falls just above the bulb of the thermometer. The freezing point is numbered 65; and the divisions are continued upwards to 8 degrees above 0. The observations are expressed in these degrees, with their decimal parts. For want of a northern room, I placed the thermometer in a chamber looking westward, where no fire was kept, and from which I excluded the sun by window shuts. But to open a communication with the external air I made a hole through the side of the house in such a manner, however, that the sun could never shine through it. So that I believe the thermometer was always nearly in the same temperature of the air as if it had been placed abroad. By the diary it appears, that though the thermometer was capable of showing the greatest heat we had last year, it would not show the greatest cold; the spirits several times subsiding so low as to be quite invisible, which in the diary is marked 101+, as the degrees of height above 0 are marked with the negative sign. . . . I shall be enabled for the future to observe greater degrees of cold by the help of a mercurial thermometer given me last winter by Colin Campbell, Esq., F. R. S., that ingenious member of the Royal Society, who misses no opportunity of promoting natural knowledge. It was made by Samuel Bewley opposite to St. Martin's Church, London, and is graduated according to Fahrenheit's scale. The divisions go upwards from the point marked 0 near the bottom of the tube as far as 112, which is called *seventh heat*, and the freezing point is number 32, and is, I think, justly placed, for having put the thermometer into snow the mercury stood at that point. Having put this thermometer close by the former, I observed in an intense cold that when the spirits of wine stood at 100, the mercury was at 16. The latter thermometer will therefore seem to estimate much greater degrees of cold than the former, and perhaps the greatest cold of this climate.

In the column of winds, I have followed Mr. Locke and Doctor Jurin, denoting the strength by the numbers 1, 2, 3, 4 and making use of a cipher, 0, to indicate a perfect calm.

I use *clear* to signify that the sky was entirely free from clouds. *Very fair* when it was almost clear, and few clouds to be seen. *Fair*, when more of the sky was free from clouds than not. *Fair with clouds*, when it was uncertain whether more of the sky was covered or clear. *Cloudy*, when more of the sky was covered with clouds than not. *Very cloudy*, when it was almost but not quite covered. *Covered*, when no part of the clear sky appeared. *Close*, when the sky was covered with one uniform thick cloud.

I would willingly have observed the quantity of rain, snow and other vapors that fell here; but my lodgings were so circumstanced that it was impracticable.

Whenever a dash is found in any column of the diary, it is to be understood that matters continue in the same condition as in the preceding observation. The chasms noted with dots, to be met with here and there were occasioned by my absence from Cambridge.

At the end of every month and every year I have set down the mean altitude of the barometer, as also that of the thermometer for morning and evening, found by dividing the sums of those altitudes by the number of observations.

I shall not pretend to make any remarks on the diary, which I know may be done to much greater advantage by any member of the illustrious Royal Society, who shall think it worth while to look over the same.

Cambridge, New England,
9 March 1744.

Following a description of a new exposure of his instruments occasioned by a change of residence, he writes:

I have always endeavored to set down the least height of the thermometer in the morning, and its greatest height in the afternoon, which is the reason why the observations are not always made at the same hour. And where there occur more than two observations in a day one of them is for the sake of the barometer, which was either higher or lower then than in the immediate foregoing or following observations.

At the end of each year are given the following tables:

1. A table of the mean, greatest, and least heights and ranges of the barometer for the year — at Cambridge, New England.
2. A table of the morning and evening heights, and of the greatest and least heights of Hawksbee's thermometer, for the year —.
3. The same for Fahrenheit's thermometer,
4. A table of winds, showing the number of observations of their blowing for each quarter of the horizon, being N to EbyN, inclusive, etc., for the year —.

Professor Winthrop's naively hinted desire for the keeping of a rainfall record was first gratified in August, 1749, from which time he kept a continuous record thru the year 1775. In 1779, the year of his death, he went back over the long record, and tabulated in the Hawksbee scale, the mean monthly temperature of each year from 1753 to 1779. He did the same for the rainfall, entering his results under "Rain from 1750 to 1776," which table he divided into "Synopsis of Rain, etc., in inches and millesimals," and "Means of Rain, etc." (This latter part from January, 1765, to December, 1773, inclusive) He recognized the unreliability of short-period averages, as is shown by his allowing fifteen years after the beginning of his rainfall observations before taking the means. The rainfall tables are here given, in full, as Tables 1 and 2. The year of maximum and minimum precipitation for each month, Professor Winthrop indicated by *W* and *D*, respectively. In the original, the ten-thousandths are exprest as common fractions.

It is remarkable that nothing remains to show that Professor Winthrop carried on an extensive correspondence with Benjamin Franklin,[11] who numbered among his varied interests

[9] See A. J. Henry: Early Individual Observers in the United States. U. S. Weather Bureau Bul. 11, p. 291 et seq.

[10] From manuscript in possession of the American Academy of Arts and Sciences. Boston, Mass.

[11] The list of the Benjamin Franklin papers in the Library of Congress, published in 1905, mentions but four letters, one of which was not to Winthrop, himself; two were from Franklin to Winthrop and one from Winthrop to Franklin.—*C. A., jr.*

TABLE 1—*Prof. John Winthrop's record of precipitation at Cambridge, Mass., from 1750 to 1775, inclusive.*

Year.	Synopsis of rain, etc., in inches and millesimals.														Remarks.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly quantities.	Means, as they arose.	
1750....	2.355	0.708	3.894	4.063	3.651	3.076	4.235	9.464	2.145	2.721	2.084	3.835	42.231	....	Wettest month was July, 1758.
1751....	4.143	6.944	2.573	3.222	2.486	6.734	5.2	W 9.475	4.144	3.157	3.08	1.928	53.086	47.6585	
1752....	2.077	3.056	4.808	2.646	1.263	5.341	4.934	1.326	0.875	7.122	1.878	3.066	38.392	45.56966	Order of months as to wetness at ——:
1753....	3.809	3.745	3.782	2.138	3.647	W 7.706	3.467	3.855	2.707	W 8.817	5.116	3.177	52.026	46.43375	
1754....	4.342	3.218	3.223	1.306	3.914	7.157	7.139	2.689	D 0.346	3.478	5.72	3.949	46.481	46.4432	
1755....	3.718	3.665	4.324	3.327	2.506	2.216	4.775	1.334	2.3	4.163	4.71	1.47	38.504	45.12966	*Dry.* *Wet.*
1756....	3.636	0.807	2.188	3.618	2.51	4.948	2.753	2.644	1.315	5.996	4.341	1.695	35.461	43.74071	September. December.
1757....	4.773	5.241	5.007	3.506	D 0.895	1.008	4.290	4.177	1.652	3.644	2.984	4.148	41.334	43.43987	April. November.
1758....	W 7.194	3.04	2.126	1.54	3.078	5.638	W 9.83	7.584	1.212	4.14	4.165	4.179	W 53.726	44.58277	March. June.
1759....	2.492	4.074	2.772	2.287	2.362	5.083	5.421	7.796	4.233	4.956	4.898	2.549	48.918	45.0163	May. August.
1760....	2.501	1.674	1.537	1.237	4.01	4.259	D 0.849	5.098	6.336	2.822	2.789	5.877	38.984	44.4679	February. October.
1761....	0.745	1.334	D 0.895	1.899	W 4.38	0.899	1.54	2.489	4.075	3.93	3.13	W 6.509	31.825	43.41433	January. July.
1762....	4.127	0.942	1.501	1.466	2.131	0.888	1.755	2.736	0.892	6.013	D 0.665	1.35	D 24.466	41.95715	
1763....	1.924	3.345	2.694	2.622	4.336	3.062	6.399	2.41	1.06	3.445	4.784	3.597	39.678	41.794	450.163 in 10 years.
1764....	D 0.047	3.371	1.405	4.494	1.898	1.747	6.054	2.168	4.393	3.204	3.565	4.581	36.927	41.4695	
1765....	1.918	D 0.596	2.891	4.017	2.668	2.566	2.738	7.783	1.422	3.085	3.856	3.113	32.653	40.9185	
1766....	1.749	0.938	4.032	3.737	3.187	2.405	5.848	4.373	2.772	5.324	1.641	1.726	37.732	40.73105	
1767....	3.328	1.006	5.386	2.712	2.922	1.595	6.178	1.639	5.727	2.354	5.156	4.302	42.315	40.81905	
1768....	2.792	2.069	1.476	D 1.23	2.538	3.322	4.269	4.811	5.66	3.046	2.184	4.357	34.754	40.6051	
1769....	1.989	1.753	3.563	1.868	3.08	D 0.753	4.208	D 1.033	4.333	D 1.825	5.915	D 1.073	31.393	40.1445	
1770....	4.247	3.153	1.062	1.636	4.03	3.523	1.392	8.851	3.713	5.307	3.171	1.187	41.272	40.1982	
1771....	2.557	W 6.975	W 6.298	4.17	4.073	3.91	3.03	1.768	2.19	2.484	5.669	2.186	45.31	40.4396	802.89 in 20 years.
1772....	1.75	4.383	2.059	W 4.92	2.279	1.807	3.959	6.863	W 7.648	6.63	3.555	3.022	48.875	40.79769	
1773....	2.788	1.218	2.794	2.312	2.256	1.912	2.731	2.555	2.938	4.009	1.959	5.142	32.614	40.4566	
1774....	2.461	1.887	2.631	2.807	3.877	3.285	2.165	3.922	3.175	2.46	W 6.288	2.396	37.353	40.3326	
1775....	0.857	1.056	0.991	....	....	....	....	....	....	....	....	....	....	....	

TABLE 2.—*Prof. John Winthrop's summary of his record of precipitation at Cambridge, Mass.*

	Mean quantities of rain, in inches and millesimals.											
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Mean quantities of 15 years	3.1922	3.01	2.8486	2.6243	2.8711	3.9876	4.5766	4.349	2.5123	4.4412	3.5936	3.461
Total of 15 years	47.883	45.164	42.729	39.371	43.067	59.816	68.65	65.245	37.685	66.619	53.904	51.91
1765	1.918	0.596	2.891	4.017	2.668	2.566	2.738	3.783	1.422	3.085	3.856	3.113
Total of 16	49.801	45.76	45.62	43.388	45.735	62.382	71.388	69.029	39.107	69.704	57.76	55.023
Means	3.1125	2.06	2.85125	2.71175	2.8585	3.8987	4.46175	4.314	2.4442	4.3565	3.61	3.438
1766	1.749	0.938	4.032	3.737	3.187	2.405	5.848	4.373	2.772	5.324	1.641	1.726
Total of 17	51.55	46.698	49.652	47.125	48.922	64.787	77.236	73.401	41.879	75.028	59.401	56.749
Means	3.0323	2.746	2.9206	2.772	2.87766	3.811	4.5433	4.3176	2.4635	4.4134	3.4942	3.3382
1767	3.348	1.006	5.386	2.712	2.922	1.575	6.178	1.639	5.727	2.354	5.156	4.302
Total of 18	54.888	47.704	55.038	49.837	51.844	66.382	83.414	75.04	47.606	77.382	64.557	61.051
Means	3.0493	2.6502	3.057	2.7686	2.8802	3.6878	4.6341	4.1688	2.6448	4.299	3.5865	3.3916
1768	2.792	2.069	1.476	1.23	2.538	3.322	4.269	3.811	5.66	3.046	2.184	4.357
Total of 19	57.68	49.773	56.514	51.067	54.382	69.704	87.683	78.851	53.266	80.428	66.741	65.408
Means	3.0353	2.6913	2.9744	2.6877	2.8622	3.6686	4.6149	4.150	2.8035	4.23305	3.5126	3.4425
1769	1.989	1.753	3.563	1.868	3.08	0.753	4.208	1.033	4.333	1.825	5.915	1.073
Total of 20	59.669	51.526	60.077	52.935	57.462	70.457	91.891	79.884	57.599	82.253	72.656	66.481
Means	2.9835	2.5763	3.0039	2.64675	2.8731	3.5228	4.5945	3.994	2.8795	4.1126	3.6325	3.32405
1770	4.247	3.153	1.062	1.636	4.03	3.523	1.392	8.851	3.713	5.307	3.171	1.187
Total of 21	63.916	54.679	61.139	54.571	61.492	73.98	93.283	88.735	61.312	87.56	75.827	67.668
Means	3.0433	2.6035	2.0114	2.5983	2.9282	3.5228	4.4425	4.2255	2.9195	4.1695	3.6107	3.22225
1771	2.557	6.975	6.298	4.17	4.073	3.91	3.03	1.768	2.19	2.484	5.669	2.186
Total of 22	66.473	61.654	67.437	58.741	65.565	77.89	95.313	90.503	63.502	90.044	81.496	69.854
Means	3.0215	2.8025	3.0653	2.6701	2.982	3.5401	4.3325	4.1136	2.8865	4.0929	3.7044	3.1752
1772	1.75	4.383	2.059	4.92	2.279	1.807	3.959	6.863	7.648	6.63	3.555	3.022
Total of 23	68.223	66.037	69.496	63.661	67.844	79.697	99.272	97.366	71.15	69.677	85.051	72.876
Means	2.96602	2.8712	3.0214	2.7678	2.9496	3.4651	4.3162	4.2333	3.0935	4.2033	3.697	3.1685
1773	2.788	1.218	2.794	2.312	2.256	1.912	2.731	2.555	2.938	4.009	1.959	5.142
Total of 24	71.011	67.255	72.29	65.973	70.1	81.609	102.003	99.921	74.088	100.686	87.01	78.018
Means	2.9588	2.8022	3.0121	2.74885	2.9208	3.4	4.2501	4.163	[page	torn]	3.6255	3.25075

a very active interest in meteorology. Franklin purchased in England an 8-foot telescope and some other instruments for Professor Winthrop, and the meager correspondence we have deals largely with these matters. In one letter from Franklin to Winthrop, appears this sentence: "I thank you much for the papers and accounts of damage done by lightning, which you have favored me with." Further than this there is nothing of strictly meteorological interest.

GOVERNMENT METEOROLOGICAL WORK IN BRAZIL.[1]

By Prof. ROBERT DEC. WARD, Harvard University.

[*Continued from the Monthly Weather Review, August, 1908.*]

THE DAILY WEATHER MAP AND FORECASTS.

The daily weather map published by the meteorological section of the Navy Department is based on observations made at Greenwich noon ($9^h\ 07^m$ a. m. Rio time) at about forty stations. Most of these are the regular stations of the Navy Department already referred to; some are under the control of the Telegraph Department (e. g., the important one at Curityba), and some are in neighboring foreign countries (e. g., Cordoba, Rosario, Buenos Ayres, Mendoza, Montevideo, and Asuncion). Several reports are missing each day. The despatches are sent by telegraph, in cipher, and include pressure, temperature, vapor tension, mean temperature of the preceding day, cloudiness, wind direction, and wind velocity. It is a serious lack not to have the amounts of precipitation during the preceding twenty-four hours given. These data would be more valuable even than the temperature and at many, if not all, of the reporting stations rain gages are already provided. The information regarding rainfall now included in the daily despatches is limited to such vague generalized statements as the following:

[1] Accompanied by Chart IX.

July 13, 1908. "It rained at São Paulo yesterday morning." "It rained during all of yesterday at Porto Alegre."

July 14, 1908. "It rained heavily at Paranagua yesterday." "At Curityba it has rained since day before yesterday."

The telegraphic despatches for the weather map are received at the central office in the Navy Department Building in Rio de Janeiro, every day between noon and 2 p. m. The map is drawn at 1:30 or 2, even if the telegrams have not all been received at that hour; it is reproduced by a mimeograph process, and copies are displayed at a few public places in Rio, and are also sent to the principal government offices. As most of the stations are immediately on the coast, the maps present a singularly incomplete appearance (see Chart IX), the isobars (usually drawn for intervals of 1 millimeter) being close together along the seaboard. At present the maps are very unsatisfactory. The forecasts relate only to Rio de Janeiro itself, and are very brief. No reference is made to temperature, as the temperature changes are slight in this region. Some of the forecasts during the writer's stay in Rio were as follows:

July 13. "Changeable weather; variable winds."

July 14. "Weather changeable from fine to unsettled; southerly winds."

July 15. "Fine weather; normal winds."

July 17. "Weather changeable; variable winds."

An examination of the maps for a week of winter weather (July 13–18, 1908) shows that for most of the coast the pressure conditions varied very little from day to day, as is to be expected, especially in the northern sections. The whole range of pressure during this period, as shown on the maps, was between 759 and 772 millimeters. A fairly heavy rain at Rio de Janeiro on July 16–18, 1908, which caused some trouble with washouts in parts of the city, furnished a good opportunity to see what general weather map features preceded and accompanied this storm.

At Rio de Janeiro the pressure rose from July 14 to 18, the noon barometer readings on these five days, as given on the daily weather map, being, respectively, 765.76, 766.38, 766.91, 769.31, and 772.26 millimeters. The writer's barograph curve showed this rise very clearly, the diurnal variation of the barometer being still fairly regular, and the reading being higher at 10 a. m. on the 18th than at any other time during two weeks spent in Rio. On July 15 the map showed a moderate and poorly-defined low, pressure 763–765 millimeters, between Florianopolis and Porto Alegre, some distance southwest of Rio, with rain at Santos that morning. Paranagua reported fresh southwest winds the preceding afternoon, with rain on the morning of the 15th (see Chart IX). On July 16 the pressure at Rio had risen, as already noted, and the low was centered somewhere to the westward of Rio, but the observations were too few to make it possible to locate the center any more definitely. At Rio the pressure had risen to 766.91 millimeters and the wind at 9:07 a. m., local time, was northwest, force 3. Santos reported rain with fresh southerly winds, and Paranagua had rain with southeast winds. The forecast for Rio was "Stormy weather, rain at intervals; southerly winds." Rain began at Rio on the afternoon of the 16th. On July 17 the low had moved somewhat north of east, and the map located it as perhaps 200 to 300 miles northwest of Rio. Santos reported rain during the 16th. The forecast was "Changeable weather; variable winds." On the 18th Rio had the highest pressure, 772.26 millimeters. The observations were too few to make it possible to say definitely what had become of the low center, but it seems probable that the storm gradually filled up and disappeared, or else past off eastward to the ocean. The forecast was for "Weather tending to improve," and on the night of the 18th it cleared off. It appears from these maps, that the rain of July 16–18 at Rio came in connection with a weak cyclonic area, and that this area did not make itself felt much nearer the equator than the latitude of Rio itself.

From the point of view of weather forecasting it appears that it would be highly desirable for the Brazilian Government (1) to increase considerably the number of stations in the southern states of Brazil, and also the number of cooperating stations in Argentina and in Uruguay; (2) to have the amounts of rainfall during the past twenty-four hours included in the daily telegraphic dispatches sent to Rio, since the amount of rainfall is more important than the temperature for most of Brazil; (3) to dispense with the daily telegraphic dispatches from the northern stations, such as Para, Natal, Pernambuco, etc., at least until there are more observers in the southern sections and in the interior. The northern States have very different weather and climatic conditions from the southern, and the critical district for forecasting purposes is that from Bahia or Victoria to the south. (4) To inaugurate a general system of weather forecasts, based on a larger number of stations, so as to include a larger area of the country, and to take up such important matters as, e. g., the prediction of frost for the coffee districts of São Paulo and other sections. It should certainly be stated in this connection that the officials of the meteorological department of the Brazilian Navy are fully awake to these needs and are doing all in their power to extend and to improve their service.

INSTRUMENTAL EQUIPMENT AT CURITYBA.

Under the control of the officials of the Telegraph Department, there are now in operation at Curityba, Quixeramobim, and Catitetê, three meteorographs, designed by Theorell and manufactured by Sörensen in Sweden, which record the principal weather elements mechanically every fifteen minutes. These instruments are reported to be working very well. The results for Curityba have recently been published. Dr. Oswald Weber,[2] the observer at Quixeramobim, has recently published the results at his station for a ten-year period. At Caitetê the meteorograph has but recently been put into operation. It is proposed to set up shortly a fourth instrument of similar pattern, on the island of Fernando Noronah, off the coast of Brazil.

The writer made a special trip in order to see the meteorograph at Curityba (lat. 25° 25′ 50″ S.; long. 49° 15′ 40″ W.), in the State of Parana. This instrument is placed in a small house on the grounds of an estate outside the city (Chacara Capanema), at an altitude of 908 meters above sea level. It is in charge of Dr. Francisco Siegel, department inspector of government telegraphs. Every quarter of an hour (96 times daily) electrical contacts are made mechanically, and the readings of the mercurial barometer (siphon pattern), wet and dry-bulb thermometers, wind direction and wind velocity are recorded in print on a roll of paper, together with the date and hour of observation. This meteorograph is a complicated piece of machinery, but the writer was assured that it does its work very satisfactorily and with great accuracy. Check readings of the instruments are made by eye several times daily. In addition to the records kept by the meteorograph, readings are made of the following instruments: rain-gages (two patterns, self-registering); Campbell-Stokes sunshine recorder; black-bulb thermometers *in vacuo*; evaporation gage (weighing); ozonometer; soil thermometers; maximum and minimum thermometers. A record of cloudiness (three times daily) is also kept. The mercurial barometer is by Sörensen of Stockholm; most of the other instruments were made by Negretti and Zambra. The exposure is fairly good, but the wind velocity is interfered with by some eucalyptus trees which are growing up near by, and it is proposed to build a new house for the meteorograph in a better location, and to move the

[2] Oswald Benno Weber. Das Observatorium erster Ordnung zu Quixeramobim. Met. Zeitsch. Apr., 1908, **25**:162-167.

other instruments as well. The Telegraph Department has recently published a summary for the Curityba station, covering a period of twenty-three years, May, 1884–December, 1907, and giving very fully the results of the observations at this important place. For length and completeness of record, and importance of location, this Curityba summary easily stands first in Brazilian climatology.

THE METEOROLOGICAL SERVICE OF SÃO PAULO.

The first organized meteorological service in Brazil, and one which has become well known by reason of its good work, was that inaugurated by Prof. Alberto Loefgren in the State of São Paulo in the year 1887, under the able direction of Dr. Orville A. Derby, then head of the Commissão Geographica e Geologica de São Paulo, and now chief of the Brazilian Geological and Mineralogical Service.

From the beginning of this service in 1887, when there were but two stations, the number of observers increased to nearly fifty in 1901, giving São Paulo the distinction of having the greatest number of meteorological observers in a given area of any South American country. The observers, chiefly teachers, engineers, and telegraph officials, are paid according to the order of their stations, from \$8 to \$12 a month, the State government having been liberal in its appropriations of money for the maintenance of the service. Observations are made at 7 a. m., 2 and 9 p. m., and about one-half of the stations are equipped with self-recording instruments.

The annual meteorological publications of the São Paulo Commission (Secção Meteorologica. Dados Climatologicos, 1887–1903) have been notable because of their completeness. The first rainfall map of São Paulo was published in the volume for 1901. In 1902 the meteorological service was reorganized under J. N. Belfort Mattos, and in 1904 the work was put under the Department of Agriculture, Commerce, and Public Works. The annual volumes for 1904 and 1905 have not yet been issued. Beginning with the year 1906 the Boletim, published quarterly, replaced the annual volume. Numbers 18–21, 1906, and Series 2a, Numbers 1–3, 1907, have appeared. These bulletins give the data for all the stations; a map for each month, showing isobars, isotherms, rainfall, cloudiness, wind, etc.; and also contain views of some of the meteorological stations. The latest Boletim (Series 2a, Number 2, 1907) contains data for thirty-seven stations. Bulletin 3 of the second series is a special publication prepared for the National Exposition at Rio de Janeiro (1908), containing an historical summary of the São Paulo meteorological service, and a brief account by J. N. Belfort Mattos, of the climatology of São Paulo, with January, July, and mean annual isobars, isotherms, rainfall, and cloudiness.[3] A daily forecast is made at the central station in the city of São Paulo for the State of São Paulo, but no map is issued. About thirty stations report daily, by telegraph, their Greenwich noon observations. This number includes several stations outside of the State of São Paulo.

THE METEOROLOGICAL SERVICE OF MINAS GERAES.

The Geographical and Geological Commission of the State of Minas Geraes has organized a meteorological service on a very much smaller scale than that of São Paulo, and has published certain Boletims on the climate of stations in that province.

This article is not concerned with publications on Brazilian meteorology and climatology other than those issued officially by Government departments, but mention may very properly be made of the numerous contributions of the late Prof. F. M. Draenert, formerly of the Agricultural College at Uberaba (Minas Geraes). His "O Clima do Brésil" (Rio de Janeiro, 1896), in reality a text-book of meteorology and climatology, is especially deserving of mention. Dr. E. L. Voss,[4] has also published an important monograph, which presents the results of observations in the State of São Paulo from 1887. References to the other publications on Brazilian climatology may be found in the bibliographies.

The writer is greatly indebted to Dr. O. A. Derby, Chief of the Mineralogical and Geological Service of Brazil, for assistance in collecting the above facts.

[3] In 1905 there was issued a previous publication by the same author, entitled Breve Noticia sobre o Clima de São Paulo.

[4] Beiträge zur Klimatologie der südlichen Staaten von Brasilien. Pet. Mitth., Ergänzungsheft 145, 1904.

NOTES FROM THE WEATHER BUREAU LIBRARY.

By C. FITZHUGH TALMAN, Librarian.

THE SAMOA OBSERVATORY.

The Royal Society of Sciences of Göttingen has just published an extensive history and description of the geophysical observatory that it has maintained at Apia, Samoa, since the summer of 1902.[1] Several charts and photographs accompany this publication. Originally established for a period of only fifteen months, chiefly with a view to obtaining seismological and magnetic observations synchronous with the observations of the German South Polar Expedition, the observatory soon proved to be so valuable that means were found to prolong its life for a further period of five years, and it now seems likely to be made a permanent institution. From the beginning the necessary funds have been provided, half by the German Imperial Government and half by the Prussian Ministry of Education. (See figs. 1 and 2.)

The work of the institution is described under four heads: Terrestrial magnetism, seismology, atmospheric electricity and meteorology. The meteorological equipment includes, besides all the ordinary self-recording instruments, a complete outfit for kite-flying, and many successful kite flights have been carried out.

The observatory is the headquarters of a network of thirty climatologocal stations in Samoa; and if the plans of its former director, Doctor Linke, are carried out, it will ultimately become the center of a system of stations extending over all the South Sea Islands from the equator to latitude 35° south.

OBSERVATIONS AT CAPE SPARTEL, MOROCCO.

The best meteorological station in Morocco is said to be that maintained in connection with Lloyd's signal station at Cape Spartel. The observations made there were first brought to the attention of the meteorological world by Prof. Theobald Fischer, in his discussion of all the available climatological data for Morocco ("Zur Klimatologie von Marokko") in Zeitschrift der Gesellschaft für Erdkunde zu Berlin, Band XXXV, 1900. The station has been in operation since January, 1894, but the results of observations, tho published in a yearly table by Lloyd's, have scarcely yet found their way into the scientific libraries. We are glad, therefore, to see a résumé of the observations for 1907 published in the September, 1908, number of Das Wetter (Berlin).

The climate of the Moroccan coast is now pretty well known, observations having been maintained for several years at Mogador, Saffi, Casablanca, Rabat, Tangier, and, as just noted, at Cape Spartel. The interior, however, with the exception of the town of Morocco (Marrakesh), remains almost wholly unknown to the climatologist.

THE MORNING ROUTINE AT A GERMAN WEATHER STATION.

Under the title "Ein Vormittag an einer Wetterdienststelle," O. Freybe, in the September number of the Das Wetter, describes in graphic detail the routine of an average morning at one of the stations of the new Public Weather Service of Germany, viz: the station at Weilburg—from the arrival of the female assistant, to begin her "hausmütterlichen Geschäfte"

[1] Ergebnisse der Arbeiten des Samoa-Observatoriums der Königlichen Gesellschaft der Wissenschaften zu Göttingen. I. Das Samoa-Observatorium, von Hermann Wagner. Berlin, 1906. (Abhandlungen der Königlichen Gesellschaft der Wissenschaften zu Göttingen. Mathematisch-physikalische Klasse. Neue Folge Band VII. Nro. 1.)

FIG. 1.—Main building of Samoa Observatory, Apia.

FIG. 2.—Instrument shelter at Samoa Observatory, Apia.

with broom and dust-pan at 7 a. m., to the delivery of the last bundle of weather maps at the post-office, about 11:30 p. m. The same well-systematized rush prevails as at the stations of our own Weather Bureau; and the same delays and hindrances occasionally supervene; when, as Herr Freybe puts it, "the temperature in the office not infrequently rises above the normal." The reports from the various European stations are transmitted from the Seewarte, at Hamburg, in two dispatches, which are received from the telegraph office by telephone and entered on the manuscript maps in twelve to fifteen minutes and four to five minutes, respectively.

A NEW CLOUD ATLAS.

From the Royal Observatory of Belgium comes a new cloud atlas,[2] designed to make familiar to the public, and especially to meteorological observers, a much amplified version of the International Classification of Clouds. This work distinguishes numerous varieties of each of the forms included in the International Classification, the Latin designations being mostly borrowed from the systems proposed by Maze, Clayton, Weilbach, Ch. Ritter and other cloud specialists. There are twenty-eight excellent half-tone illustrations.

Since Clayton published his exhaustive historical sketch of cloud nomenclature in the Annals of Harvard College Observatory, Vol. XXX, Part IV, (Cambridge, Mass., 1896), several elaborate systems of classification have been proposed, so that there is now quite a bewildering variety of names to choose from in designating the subdivisions of the simple types included in the International Classification. Fortunately, however, the latter classification alone answers the ordinary requirements of meteorological observation, and has been adopted by nearly all the meteorological services and independent observatories of the world.

COMPOSITION OF THE AIR AT HIGH ALTITUDES.

Ciel et Terre of October 1, 1908, contains a brief account of experiments carried on by M. Teisserenc de Bort to determine the composition of the air in the isothermal zone or "warm layer" of the atmosphere, especially with regard to its richness in the rare gasses, helium, argon, etc. A glass tube, exhausted of air and sealed at both ends, was attached to a sounding balloon. When the apparatus reached a sufficient height a small hammer, actuated by the meteorograph, struck one end of the tube and broke it, admitting the air. The tube was subsequently resealed by an electric current sent thru a platinum wire coiled around the tube at the broken end. The amount of air thus secured was too small to admit of quantative chemical analysis, but was studied qualitatively by means of the spectroscope. Two methods were followed in different experiments; in one all the elements of the air except helium and neon were removed thru absorption by carbon; in the other the argon was separated first.

Analysis revealed the presence of argon and neon in the samples of air taken at all altitudes, from 8 to 14 kilometers. Helium was found in most of the samples, except those taken at the greatest altitude attained, viz, 14 kilometers. Whether krypton was present in the samples could not be determined.

An account of these investigations also appears in the Quarterly Journal of the Royal Meteorological Society, July, 1908, p. 189–190.

METEOROLOGY AT THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Among the many interesting papers presented before *Section B—Physics* of the American Association for the Advancement of Science at the summer meeting held in the Wilder Laboratory of Dartmouth College, Hanover, N. H., June 30, 1908, two seem to be of special interest to students in meteorology and climatology. The following abstracts of these papers appeared in Science, of August 21, 1908:

A study of overcast skies.—E. L. Nichols, Cornell University.

The spectro-photometric measurements which formed the basis of this paper were carried out, during the travels of the author in Europe, by means of a handy portable apparatus which gave the opportunity to compare the skies of widely different localities and at different times of day. The relative intensities of the individual color-components were very different with different kinds of sky. The radiation was rarely selective but almost always of the "black body" type. There is, however, almost

[2] Vincent, J. Atlas des nuages. Bruxelles, 1907. (Annales de l'Observatoire royal de Belgique. Nouvelle série. Annales météorologiques.)

always an absorption band in the violet during the middle of a bright day in the mountainous regions. Its development is coincident with the gathering of a slight mist.

The illumination from an unclouded sky is about the same as from a completely clouded sky. The most light, however, comes from a sky which is partly covered with clouds. The so-called "cumulus" clouds produce especially good luminosity.

The isothermal layer of the atmosphere.—W. J. Humphreys, Mount Weather Meteorological Observatory.

The temperature of the atmosphere decreases more or less uniformly with increase in elevation above the surface of the earth until an elevation of from 30,000 to 60,000 feet is reached, where the temperature is −50° to −60° C. From this elevation up as far as balloons have gone the temperature remains practically constant. This is explained as the result of radiation, mainly from the moisture in the [lower atmospheric strata which has] an effective radiating surface of great extent in comparison with elevations reached by balloons.

The means of locating this surface was considered. The relative proportion of the different constituents of the air is different at different elevations, the proportion of water vapor being relatively great in the lower layers. Calculation shows the temperature of this "effective radiating surface" to be about −33° C. (The calculations were carried through in detail before the joint session.)

This paper was afterwards (on August 27) read at the Put-in-Bay meeting of the Astronomical and Astrophysical Society of America, and again before the Philosophical Society of Washington, D. C. It will appear in full in the Astrophysical Journal for December, 1908. It is interesting to note that Professor Humphreys had anticipated by a few weeks only, the somewhat similar but wholly independent explanation offered for the same phenomenon by Mr. Gold at the Dublin meeting of the British Association on September 2, 1908.—*C. A. jr.*

THE ISOTHERMAL LAYER OF THE ATMOSPHERE.

[Reprinted from "Nature," London, of October 1, 1908, p. 550-2.]

The important discussion of which we give here a detailed account was organized by the committee of Section A of the British Association, and took place at the recent meeting at Dublin.

It was intended that M. Teisserenc de Bort should open the discussion, but he was unable to be present and sent the following communication:

Permit me to open the discussion on the isothermal layer and the inversions of temperature which are found there by recalling in a few words the results obtained during the past twelve years. Our experiments at Trappes have shown, in the first place, that the temperature ceased to diminish at a certain height after having passed thru a point of maximum rate of decrease about 3,000 meters lower down.

The altitude at which the diminution ceases changes with the character of the weather; it may descend as low as 8 kilometers at Paris during a cyclone, while it rises as high as 13 or 14 kilometers in high-pressure areas and in front of large cyclones.

I indicated these peculiarities for the first time in October, 1901, in a communication to the Luftschiffahrt Verein at Berlin, then in a communication to the Meteorological Society of France in March, 1902, and I developed these conclusions in a note to the Académie des Sciences in April, 1902.

A short time after, in the early part of May, 1902, Professor Assmann showed from the ascents of six rubber balloons that not only was there a cessation of the decrease in temperature, but also an inversion. This inversion had also been very marked in the first ascents by Hermite and Besançon, but Professor Assmann sought to explain it as being due to the effect of solar radiation on the thermometer while the ventilation produced by the rapid ascent of the balloon showed that it could not be referred to such an error in the thermometer record.

Having once demonstrated the existence of this isothermal layer for places in the neighborhood of Paris, we sought to find the evidence of it in other regions in order to show that it was a general phenomenon. Ascents made by us and our assistants in the winter of 1900-1, by M. de Quervain in Russia, by Mr. Eggeberger at Bath, England, in 1902, have made it evident that the phenomenon was a general one. On referring to the results of the international ascents made in different countries, it is seen that the cessation of the temperature decrease is found in the case of all the balloons sent up, and that it is impossible to refer it to insufficient ventilation, since the phenomenon was well marked in ascents made during the night. Since this time, ascents made on board the *Princesse Alice* by Professor Hergesell in 1905 have furnished evidence of the existence of the layer near the Azores; ascents made in the United States by Mr. A. L. Rotch have furnished evidence of its existence there with the peculiarities I have indicated, i. e., high up over high-pressure areas and low down over low-pressure areas.

The expeditions of the *Otaria*, organized in conjunction with my friend, Mr. Rotch, have proved the existence of the zone in the Tropics, and have shown it is further from the earth near the equatorial regions where the trade winds meet.

Finally, the ascents made at the end of the winters of 1907 and 1908 by the French-Swedish expedition organized by the Observatory of Trappes, with the support of Professor Hildebrandsson, have shown that near the Arctic Circle, at Kiruna, the layer exists and possesses general characteristics analogous with those found in these regions.

The results of series of daily ascents for eight, ten, or more days in succession in February, 1901. March, 1903, and May, 1904, have proved that the change of altitude of the point where the temperature ceases to fall is accompanied by changes of temperature of 10° C., 15° C., 20° C., in an interval of a day or two at heights between 9 and 13 kilometers, variations great enough to be felt near the surface during the same time.

Thus the equalization of temperature in the course of the year which had been supposed to be nearly complete at 8 or 9 kilometers altitude does not exist, but, on the contrary, sudden changes of temperature occur with the passage of cyclones and anticyclones which would furnish to an observer in those regions the chief evidence of the changes occurring at the surface.

Causes of the isothermal layer.—The summary of the observed phenomena has led me to this conclusion, that the cessation of the temperature diminution is due to the fact that there is at these heights no considerable vertical convection.

The fact that one meets with layers of air thousands of meters thick where the temperature increases and decreases rapidly, and others where it is stationary, is incompatible with the existence of motion of the air accompanied by pressure variations, which always tend to produce a vertical temperature gradient more or less near that for the adiabatic state. It does not follow that the movement in the isothermal layer must be horizontal, but that it takes place along the isobars without crossing these surfaces nearly in the manner in which a body rolls on an inclined plane.

These ideas have been developed in several communications, in particular at the Conférence d'Aérostation scientifique at St. Petersburg in September, 1904.

In the absence of M. L. Teisserence de Bort, Doctor Shaw opened the discussion. He explained what was the main feature of the phenomenon, and showed how it had been corroborated by *ballon sonde* ascents made in England. The temperature of the air decreases in the lower layers on the average at 5° or 6° C. per kilometer up to a height of about 10 kilometers. Above this height the temperature ceases to fall rapidly and falls very slowly indeed, or remains constant, or in some cases increases. It has been suggested that the phenomenon might be due to a change in the composition of the air at great heights. M. L. Teisserenc de Bort had succeeded in sending up balloons carrying vacuum tubes which were opened and resealed electrically at a height of 14 kilometers. The samples of air so obtained were examined spectroscopically, and the examination showed that there was no change in the composition of the air sufficient to account for the cessation of temperature diminution.

Remarks by A. L. Rotch.

Mr. Rotch said that the only *ballons sondes* which have been sent up in America were those dispatched by him. Since 1904 76 rubber balloons have been launched from St. Louis and all but one have been recovered. The majority of those which rose higher than 12,870 meters (8 miles) entered the stratum of relatively high temperature.

All the ascents occurred after sunset, so that there can be no question as to the effect of solar radiation. The instruments used were of M. Teisserenc de Bort's construction, and were verified for low pressures and temperatures before and after the ascents. The warm stratum, which was not isothermal but became warmer with increased height, was at its lowest level in summer, having a minimum temperature of −54.6° C. at 12,000 meters. During the autumn of 1907 the stratum of warm temperature was penetrated eight times, the mean minimum temperature of −60.5° occurring at 12,370 meters.

The changes in the level of the minimum temperature from day to day were large. Thus the minimum of $-67.1°$ C. at a height of 14,500 meters on October 8 was followed two days later by a descent of the minimum of $-62.2°$ C. to 12,000 meters. In the first case the temperature at the highest point reached, viz, 16,500 meters, was $-58.1°$ C., and in the second case, when 15,000 meters was attained, $-56.0°$ C. On November 6 the minimum temperature of $-52.2°$ C. occurred at 9,700 meters, but the place of occurrence of the minimum of $-63.1°$ C. had risen to 14,250 meters on November 8. The temperatures at the highest points reached were $-50.5°$ C. at 10,000 meters and $-60.2°$ C. at 15,380 meters, respectively.

These observations, made near latitude 35° north, show the warm stratum to be at a distinctly higher level than in northern Europe, whereas the results obtained by the expedition sent jointly by M. Teisserenc de Bort and the speaker to explore the atmosphere over the tropical Atlantic in 1906–7 show that it was there considerably higher. In fact, the observations obtained over the equator up to 15,000 meters show no reversal of temperature, and a lower temperature than exists at a corresponding height in northern latitudes.

Remarks by Mr. Cave.

Mr. Cave said that during the last week in July he was able, by means of theodolites, to follow four balloons into the isothermal layer. From these observations it appeared that the wind velocity increased to a maximum just below the isothermal zone, and decreased rapidly above. The wind velocities were very high, and most of the balloons went out to sea; one, sent up on July 28, was recovered. From the record of the meteorograph it appears that the isothermal layer was entered at 11,500 meters; the theodolite observations indicated that this was the height of the maximum wind velocity; above this the velocity dropt to eight miles per hour at 13,000 meters.

Remarks by W. H. Dines.

Mr. W. H. Dines said that he knew there had been some doubt exprest about the existence of the isothermal layer, and possibly there were still some who thought that the results obtained were due to instrumental errors. Such a view was now quite untenable, for about 70 ascents had been made in the British Isles during the last eighteen months, and the results entirely confirmed those previously made on the Continent and in America, altho the instruments used for recording the temperature were of totally different patterns. These ascents had mostly been made about the time of sunset so that no possibility of solar influence might be present, but in every one of the 60 cases, when a sufficient height had been reached, the temperature gradient became negligible or of opposite sign. After calibrating many instruments he was convinced that the temperatures recorded were, with but few exceptions, correct within 2° or 3° C.

The results, however, were most remarkable, and it was not surprising that their accuracy had been doubted. It had been found that over places only a few hundred miles apart, and at the same time, the temperatures might be widely different, and within the same week and over the comparatively small area of the British Isles differences of 30° C., had been recorded, namely, $-40°$ C. at 15,000 meters at Limerick on July 27; $-60°$ C. at Pyrton Hill, Oxon., on the same date; and $-69°$ C. at Pyrton Hill on July 29, and again on July 30. Very similar differences between Manchester, Ditcham Park, and Pyrton Hill had been noted on previous occasions.

The absence of any temperature gradient in the air is definite proof of the absence of any vertical circulation, but this alone did not present any difficulty. He had always thought that the vertical circulation was chiefly due to the heat set free when aqueous vapor was condensed to water, and since it was known that the relative humidity was small at great heights, it might well be that above 10 or 12 kilometers there was no aqueous vapor, and therefore no vertical circulation. The difficulty was how large temperature differences could exist at small distances apart without producing convection currents. In a mass of gas at rest under a conservative system of forces the isobaric or isothermal surfaces must be coincident. In this case the temperature observations led to two contradictory results—they showed that there was no circulation and also that the isobaric and isothermal surfaces were not identical. At a height of 15 kilometers a very small change of pressure would produce a large adiabatic change of temperature, but it was difficult to see how with so small a mass of air left above, changes of pressure could be produced. The accelerations produced by curvilinear motion of the air particles, and by the effect of the earth's rotation on a moving body appeared to be far too small for the purpose. Was it possible that the upper air could carry a sufficiently strong electric current to be influenced by the earth's magnetic field, and so produce forces comparable with gravity? Professor Schuster had suggested some such origin for the daily variation of the magnetic declination.

Remarks by Mr. Gold.

Mr. Gold said that any explanation of the existence of the isothermal layer must take into consideration the effect of atmospheric radiation. On the assumption that the radiation per unit area from a layer of gas was proportional to the mass of gas in the layer, and that the absorption followed the same law, he had worked out some results for the earth's atmosphere. If the atmosphere were of uniform constitution, so that the absorption by a layer of air of given mass was the same at whatever height the layer was taken, then the state of convective equilibrium could not exist to heights greater than those corresponding to a pressure equal to half the surface pressure. He found that for greater heights than this the radiation absorbed from the earth and the rest of the atmosphere alone was greater than that emitted at a temperature corresponding to the state of convective equilibrium. In consequence of this the temperature of the air in the upper layers would rise, and there would be a further increase owing to the absorbed solar radiation. In the actual case, the absorbing power of the atmosphere diminishes with increasing height owing to the diminution in the proportional amount of water vapor present. The absorbing power was therefore taken to be $a \div (q-p)$, where a and q are constants. Two values were taken for q, for one of which the diminution in absorbing power was quicker, in the other slower than the diminution in the proportion of water vapor present. The value of a was deduced from the observations of Langley, Paschen, and others.

The conclusions arrived at were:

(1) If the temperature gradient in the lower layers of the atmosphere is such that T varies as $p^{1/4}$, i. e., is approximately adiabatic, and if the upper layer is isothermal, then the state $T \propto p^{1/4}$ must extend to a height greater than that for which $p=p_0 \div 2$, and in general less than that for which $p=p_0 \div 4$, where p_0 is the surface pressure.

(2) The temperature in the lower layers cannot be maintained by absorption of terrestrial and solar radiation; these layers tend to grow cooler, and their temperature is kept up by the supply of heat thru convection from the earth's surface and by condensation of water vapor in the atmosphere.

(3) The lowest possible temperature in the atmosphere over a place at temperature 300° A. (absolute), must be greater than 150° A., or 210° A., according as the atmosphere radiates and absorbs thruout the spectrum or transmits freely 25 per cent of the earth's radiation.

Remarks by Professor Turner.

Professor Turner said that whereas meteorologists were, perhaps, primarily concerned with the facts themselves, and

physicists with the causes of them, astronomers were interested in the effects of the existence of this isothermal layer, especially in the phenomena of atmospheric refraction. It had been usual to make certain assumptions about the upper air for the calculation of refraction, and these assumptions were now shown to be wrong. Were the refractions calculated on such assumptions wrong? The answer seemed to be that very rough assumptions were sufficient for astronomers; he had found, for instance, that the assumption of two homogeneous shells of air would give empirical results corresponding closely to the facts observed.

Further, no very great improvement was found by adding a third shell—the chief step came in taking two instead of one. Possibly this fact, that two shells were absolutely necessary, but a third was not so much needed, was in some way connected with the existence of two principal regions in the atmosphere.

Prof. J. J. Thomson asked if there was any indication of the thickness of the layer, and remarked that the ionisation in the atmosphere was a maximum at a layer considerably below this layer.

Doctor [Gilbert T.] Walker stated that the Indian peasants were so ignorant that he had not yet ventured on sending up *ballons sondes* there, the chances of recovering them being so remote.

DAMAGES BY FLOOD AT KANSAS CITY, MO.

Thru an oversight, the statistics regarding flood damage at Kansas City, Mo., were unduly abbreviated in the MONTHLY WEATHER REVIEW for July, 1908. The paragraph on p. 206 relating thereto should read as follows:

> The damage at Kansas City was very small compared with that caused by the flood of 1903, in fact, the damage to property was very light considering the size of the flood. Twenty-three business institutions in the bottoms, some in Kansas City, Mo., and some in Kansas City, Kans., report a total damage to property of only $91,500. The same number report a total loss by enforced suspension of business of $168,000 and value of property saved by the flood warnings of the Weather Bureau of $1,324,000. These figures multiplied by 10 will, in each case, fairly represent results, making a grand total of damage to property of $915,000 and loss to business of $1,684,000. The value of the Weather Bureau warnings is conservatively estimated at $5,000,000. The railroad losses were only about $350,000.

With this alteration the total losses in the Missouri Valley from Plattsmouth, Nebr., to Boonville, Mo., amount to $10,919,000.—*C. A., jr.*

THE SCIENTIFIC ASPECT OF A BALLOON VOYAGE.

By H. H. CLAYTON. Dated Bluehill, Mass., September, 1908.
[Reprinted in part from the Boston Sunday Herald, August 9, 1908.]

The trip described below was made from North Adams, Mass, on July 29, in company with Mr. Charles J. Glidden, of Boston.

The morning of July 29 seemed very unfavorable for an ascent at North Adams, Mass., since the sky was covered with a very low sheet of cloud which seemed to threaten rain. By 10 o'clock this stratum of cloud had cleared away. The sun came out, brilliantly hot, causing a rapid rise in temperature. While we were discussing the arrangements for the voyage and the time of leaving, we noticed that clouds such as are usually associated with thunder-storms had already begun to form over the mountains, and it seemed wise to postpone the beginning of the voyage until the late afternoon, a time which Mr. Glidden had previously found to be especially favorable for balloon voyages.

By 1 o'clock the clouds had developed enormous proportions over the Hoosac Mountains, and showed the overspreading tops characteristic of local thunder-storms. Under these conditions it seemed unsafe for a balloon, and the voyage was postponed until the clouds had begun to show signs of disappearing. Finally, at 4:30 p. m., the ascent was begun.

The wind was at the time very light, but showed a prevailing direction from slightly south of west. As the balloon rose it moved with increasing speed directly eastward toward the Hoosac Mountains. After we had risen to a height of about 2,000 feet we were traveling eastward at a speed of about 6 miles an hour.

THE UPDRAFT.

The temperature at the ground when we left was 86° and already it had fallen about 10°. As we approached the mountain, the balloon steadily rose to a greater height, indicating a strong ascent of air over the peak, where clouds still were seen but of much less proportions than in the earlier afternoon.

As the balloon came near the summit of the mountain it was caught in the whirling vapor and carried upward to a height of about a mile, the ascent being aided, however, by the throwing out of ballast in hopes that we might rise above the top of the cloud. As we approached the cloud the shadow of the balloon was seen distinctly outlined on the ragged mass of vapor, surrounded by rings of colored light.

The updraft over the mountain is indicated in outline in figure 1. This shows the clouds formed in this ascending current, and the balloon at the point of entering the upper portion of the cloud. The observations in the balloon showed that the temperature at this point had fallen to 68°; the clouds were formed by the chilling of the air due to its own expansion and the condensation of the invisible moisture which it contained.

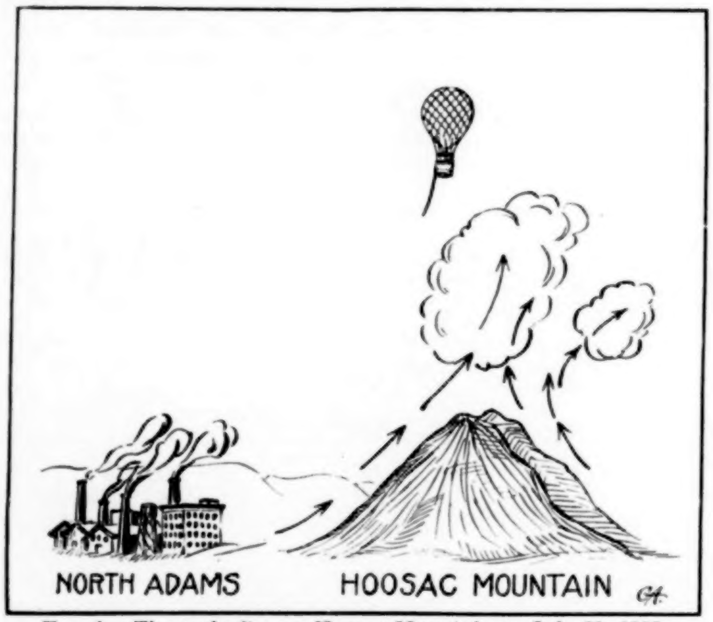

FIG. 1.—The updraft over Hoosac Mountain on July 29, 1908.

As the balloon passed the mountain summit and lost the ascending current which sustained it it began to descend rapidly, because in rising into the thinner air it had lost a part of its gas, which had flowed out at the bottom of the bag. Hence, the bag being unable to support its previous load, it was necessary to throw out sand very quickly to prevent falling entirely to the ground.

Notwithstanding, we fell so rapidly that the sand was past, the balloon dropping faster than the finest grains of sand. The rate of descent was about 6,000 feet a minute. This continued until the trail ropes touched the tops of the trees, after which the balloon, being relieved of part of its weight, floated smoothly along.

THE PATH OF THE BALLOON.

The path of the balloon from North Adams to its place of landing is shown by the broken line, figure 2. An analysis of this course shows that its bend was due to an indraft of air

toward the mountain, combined with the general wind then prevailing.

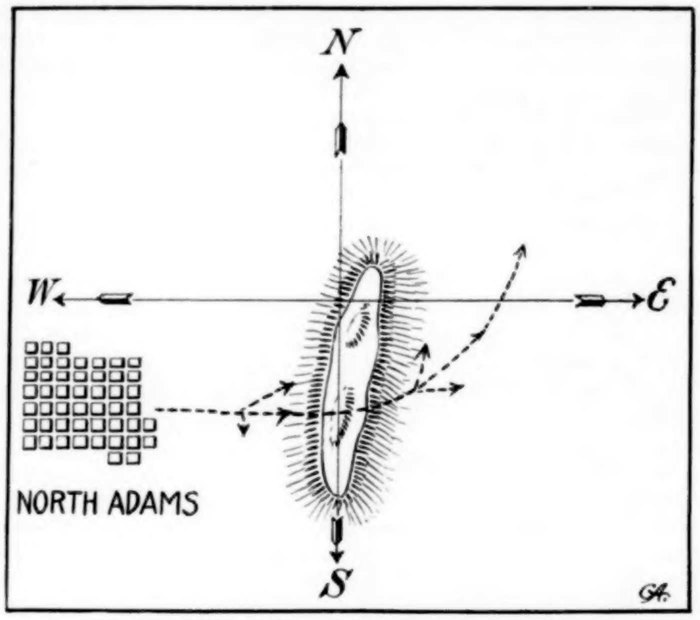

FIG. 2.—Diagram of the path of the balloon from North Adams, Mass., across Hoosac Mountain, July 29, 1908.

Between the Hoosac Mountains and North Adams, there is drawn a heavy arrow along the track, and on either side of the heavy arrow are drawn other arrows, the longer one showing the prevailing wind, the shorter showing the wind caused by the heated air flowing up the sides of the mountain. The flight of the balloon was the resultant of these two winds.

On the east side of the mountain a similar heavy arrow is drawn and the prevailing winds shown in the same way. So that the track of the balloon was directly toward the east on the west side of the mountain, but turned toward the northeast on the eastern side.

Noting the short arrows, which are intended to represent the local component of the wind under the influence of the mountain, it is seen that the wind tended to flow round and up the mountain slopes in the same way that air flows round and into a center of low pressure. And just as clouds and showers are found round the central area of a low pressure, so clouds were found round the summit of the mountain.

ASCENDING AND DESCENDING CURRENTS.

Messrs. Stevens, Hawley, and Van Sicle, who ascended at Dalton, Mass., earlier in the day, were drawn into one of these massive clouds found about the mountain, and there encountered a tremendous ascending current that carried them upward with frightful speed to 8,000 or 9,000 feet, after which, having lost much gas, they descended very rapidly.

Such experiences, however, are not rare. Several aeronauts, including Wise in America and Captain Goss in Germany, have related similar experiences in which the attendant phenomena were even more violent than those related by Mr. Stevens. In no case, however, has the aeronaut suffered any injury. Even if all the gas were driven out of his balloon, as was the case with Wise, the bag would act as a parachute and land the aeronaut without serious damage.

A mountainous region is not as favorable as level country for long voyages in balloons, because the ascending currents which prevail there cause the balloon to lose much gas. In taking a pleasure voyage over such a country, it is usually necessary to pass above the ridge of the mountain, and in doing so the balloon necessarily loses gas, even if the current ascending the side of the mountain is not strong. Immediately after the ridge is past, the balloon, no longer supported by the current, falls by its own weight and is further aided by descending currents which probably prevail on the leeward side of the mountain. This effect causes the aeronaut to lose his extra ballast rapidly and makes it difficult to float at a uniform height, which is the desideratum in ballooning. As opposed to the ascending currents of air, which are found over mountains, balloonists find that there are strong descending currents of air over cool portions of the earth's surface, like lakes and dense forests. A balloonist in Switzerland tells of being drawn down to the surface of a lake and held there by the descending current so that he was unable to rise again.

The following table, Table 1, presents the result of the records kept by Mr. Clayton on this ascent at North Adams:

TABLE 1.—*Meteorological observations by H. H. Clayton in balloon ascent with Charles J. Glidden on July 29, 1908.*

Time, 75th meridian.	Altitude of balloon above sea level.		Temperature.		Relative Humidity.	Wind.	
						Direction.	Velocity.
	Meters.	*Feet.*	°*C.*	°*F.*	*Per cent.*		*Mi. p. h.*
4:35 p. m.	240	787	29.1	84.4	58	w.	5
4:44 p. m.	500	1640	26.7	80.1	64	w.	6
5:00 p. m.	1000	3281	22.4	72.3	76	w.	7
5:13 p. m.	1500	4921	18.5	65.3	91	w.	7
5:15 p. m.	1560	5118	18.0	64.4	93	wsw.	7

Remarks.—The balloon left the ground at 4:35 p. m.; 5:09 p. m. among clouds; 5:12 p. m. a glory, two colored rings, was observed about the shadow of the balloon; 5:15 p. m. passing thru a cumulus cloud. Wind changed from W to WSW at 1,500 meters when crossing Hoosac Mountains and was from SW about 5 miles an hour on landing in W. Monroe, six miles ENE of North Adams. The sky was clear during the flight except for a few cumulus clouds over the mountain.

THE SECOND VOYAGE.

On September 10, 1908, Messrs. Clayton and Glidden made a more extended voyage, this time from Springfield, Mass. They remained in the air nearly five hours, from 0:38 to 5:23 a. m. and traveled from Springfield to Bridgewater, Mass. Table 2 gives some of the results of their observations during this trip.

TABLE 2.—*Observations during balloon voyage by Charles J. Glidden and H. H. Clayton, September 10, 1908, from Springfield, Mass., to Bridgewater, Mass.*

Place.	Time, 75th meridian.	Distance.	Velocity.	Traveling toward—	Height.	Temperature.
	a. m.	*Miles.*	*Mi. p. h.*		*Feet.*	°*F.*
Springfield	0:38	....	....	....	125	59
Chicopee River	1:04	5	11.5	ne.	900	57
Central Massachusetts R. R.	1:48	9	12.3	ne.	1,000	50
Ware	2:30	7.5	10.7	ese.	1,500	60
North Brookfield	2:55	7.5	18.0	ese.	1,500	57
Worcester reservoir	3:18	8.5	22.2	e.	1,400	....
Worcester	3:30	4.5	22.5	....	....	....
Millbury	3:35	3	36.0	se.	3,000	60
North Pond	3:53	9	30.0	se.	3,000	....
Milford	4:08	4	16.0	ese	1,500	....
Neponset reservoir	4:45	14	22.7	....	....	....
East Foxboro	4:51	2.5	25.0	e.	800	....
Easton	5:04	5	23.3	e.	600	53
Bridgewater	5:23	7	22.1	e.	....	....
Total	....	86.5				
Mean in four hours	....	45	18.0	e.	....	....

Straight line distance = 82 miles.

THE METEOROLOGICAL WORK OF THE UNIVERSITY OF JURJEV (DORPAT), RUSSIA.

By ELMAR ROSENTHAL. Dated Tiflis, September 21, 1908.

The Meteorological Observatory connected with the University of Jurjev (Dorpat), has recently issued a volume of memoirs written by students of the university. The work was planned and supervised by Prof. B. I. Sresnevsky, Director of the observatory. The memoirs are written in Russian and followed by brief abstracts in German. The following gives a short account of these papers.

Agrinsky.—*The relation between rainfall and the fluctuations in level of the Embach.*

Records of twenty-six rain-gage stations distributed over the drainage basin of the little river Embach are used. The level of the river shows very distinctly the influence of the precipitation, every rainfall producing a well-defined fluctuation in the height of the stream. Heavy rains of short duration are of less influence than rainy periods of several days. But all such fluctuations are of minor importance in comparison with the great annual period peculiar to most of the Russian rivers. After the melting of the snow in the early spring the level of the river rises rapidly, reaching its maximum height within less than two weeks after the first rise. The water level then decreases slowly to the mean level of early spring, which it attains only at the end of summer, and reaches its minimum at the end of September. The fluctuations produced by the rainfall do not entirely mask this general period. A small secondary maximum in the late autumn is caused by the precipitation of this season.

Vinogradov.—*The relation between barometric gradient and wind velocity near Jurjev (Dorpat).*

The observations at three stations near Jurjev furnish the data for calculating the relation between the wind velocity and the pressure gradient. Direct computation does not reveal an accurate relation between these elements. The author finds that with the gradient as argument, a velocity of 1 to 2 meters per second belongs to a zero gradient. Inversely, using the wind-force as argument, he finds for the velocity 0 a gradient of 0.6, 0.7, or 0.8. The difficulty disappears if one calculates the frequency of both elements and compares gradient and velocity for equal frequencies. Then an exact relation is found to exist, both elements become 0 for the same frequency and increase in a constant ratio. This method was suggested by Prof. B. I. Sresnevsky about twenty years ago. Further details will be found in the original paper.

Pokrovsky.—*European cyclone tracks for 1890–92.*

This is a revision of an earlier paper by Mr. Rybkin. As that author had employed methods differing somewhat from the usual ones, and his results did not fully agree with other investigations, a recalculation seemed desirable. The method now employed is the same as that of Professor Sresnevsky in his earlier works on cyclone tracks, and the results are in full agreement with this author. The mean direction of the tracks is ENE. The velocity of winter cyclones diminishes, while that of summer cyclones increases within the limits of Europe. In general, the tracks are curves concave toward the north. Summer cyclones become stronger during their passage over Europe, while winter cyclones diminish in intensity. The mean velocity is about 33 kilometers per hour.

Meyer.—*Some experiments with hair hygrometers.*

The influence of pressure was investigated and found to be inappreciable. No variation of the hygrometer reading (within 1 per cent) could be found when the pressure varied from 50 millimeters to 760 millimeters. Further experiments were made in order to study the variations caused by ether vapor introduced into the constant humidity chamber. When the humidity is diminishing the hair of the hygrometer contracts. The theory of the hair hygrometer by Professor Sresnevsky explains this contraction by the action of the surface tension of little water bubbles included in the capillary canal of the hair. The ether vapor tends to diminish the surface tension, and, therefore, should cause a lengthening of the hair. This was indeed observed, but the lengthening did not reach the calculated value. It is to be hoped that further investigations will explain the discrepancy.

Radetzky and Sresnevsky.—*The arrangement of cirrus clouds.*

The purpose of this investigation was to determine whether the observation of cirrus radiant could give any valuable scientific result or not. There is a well known hypothesis that the bands or stripes of feeble cirri radiate from the cloudy area of a cyclone. The investigation shows, however, that this assumption is not well founded. The authors failed to establish any relation between the directions of the cirri and the isobars. But another result of interest was obtained. In many cases the direction of the cirri was shown to be nearly identical. Thirty per cent showed nonparallelism over the vast area of European Russia. A marked parallelism in arrangement was established for 40 per cent of all cases, and the remaining cases were doubtful. It should be added that the observations available for this investigation were not of a quality desirable for scientific study, the casual observers being not sufficiently familiar with the methods of cloud observing, and the observations being incidental rather than of intention. Further investigations, therefore, would be interesting and desirable.

Kharshan.—*The diurnal and annual periods of the humidity at Jurjev (Dorpat).*

The annual rate was determined from observations extending thru 35 years. We give here the result for the average relative humidity only. January, 89.8; February, 86.8; March, 83.9; April, 75.9. May, 69.2; June, 69.7; July, 73.2; August, 78.6; September, 83.9; October, 87.5; November, 91.0; December, 90.6 per cent. The diurnal rate was determined for each month separately from automatic records for the year 1897 only. This latter part of the investigation will be continued.

Kurrik.—*Sensitometer observations during the years 1902–1906.*

An improved Scheiner's sensitometer, as described by Andresen in the "Annales de l'observatoire météorologique du Mont Blanc" for 1900, was used. The instrument was sheltered from the diffused sky light by a long tube; "Ilford" photographic paper was used. After reducing the observations to equal thickness of the atmosphere, its transparency was found to be a little less during the summer and somewhat greater during the winter than that found by Andresen. It was found that the atmospheric water vapor was of great influence. Let e be the vapor tension, then the absorption coefficient is given by the formula:

$$\text{coeff.} = 0.148 \pm 0.007 + 0.015\, e \pm 0.002\, e,$$

where the probable error is very small. It follows from these considerations, that the magnitudes of stars, when determined by measurements of photographic plates, need a correction due to the vapor tension prevailing during the exposure.

Detishchev.—*Cold waves during the years 1901–1904.*

Cold waves are unknown in western Europe, but they are very common in the interior of large continents such as North America and in Russia. In the latter country the existence of such waves was first detected by Professor Sresnevsky. In many cases the propagation of these waves is so rapid, that a study of the mean daily temperature is often insufficient to detect them. The investigation may be founded on three different characteristic values, which give in general somewhat different results, namely, 1. On a particular daily thermometer reading, for instance at the morning observation; 2. On the monthly minimum temperature, which is published in the international summaries for every station and is thus available for studying the most important cold waves in regions for which daily observations are not published; 3. On the greatest monthly departure of the daily means from the monthly mean.

The present investigation is based on the morning temperature and a full list of the cold waves for 1901–1904 is presented. An abstract of an earlier paper by Professor Sresnevsky, embracing the years 1890–1900 is added. As a general rule the

cold waves appear first in the region northeast of Lake Onega. The wave then moves, in general, southeastward with a velocity of 600 or 700 kilometers per day, forming a long curved band. In most cases the wave finishes in the southeastern part of European Russia, but some could be traced as far as India and the coast of the Pacific Ocean. Professor Sresnevsky adds some theoretical remarks on the mechanics of these cold waves, for which the reader should consult the original German abstract.

PRIZE OFFERED BY THE GERMAN METEOROLOGICAL SOCIETY.

Dated Berlin, October, 1908.

At the request of Prof. G. Hellman, President of the German Meteorological Society, we publish the following announcement, at the same time expressing the hope that many observers will feel impelled to enter the competition. It is true that the research corps at Mount Weather, Va., are in the most favorable position to compete, but there are available in this country, several sets of the published results of the International Commission for Scientific Aeronautics, and the Editor will gladly do all that he can to aid any of our men in the preparation of a creditable essay in this competition.

Preisausschreiben der Deutschen Meteorologischen Gesellschaft.

Die Deutsche Meteorologische Gesellschaft schreibt einen Preis von 3000 (drei Tausend) Mark aus für die beste Bearbeitung der bei den internationalen Aufstiegen gewonnenen meteorologischen Beobachtungen, soweit sie veröffentlicht vorliegen.

Bedingungen.

1. Es steht den Preisrichtern frei, geeignetenfalls den Preis zu teilen.
2. An der Preisbewerbung können sich Angehörige aller Nationen beteiligen.
3. Die anonym einzureichenden Bewerbungsschriften sind in deutscher, englischer oder französischer Sprache zu verfassen, müssen einseitig und gut lesbar geschrieben, ferner mit einem Motto versehen und von einem versiegelten Umschlag begleitet sein, der auf der Aussenseite dasselbe Motto trägt und inwendig den Namen und Wohnort des Verfassers angibt.
4. Die Zeit der Eisendung endet mit dem 31. Dezember 1911, und die Zusendung ist an den unterzeichneten Vorsitzenden der Gesellschaft (Geheimen Regierungsrat Professor Dr. G. Hellmann, Berlin W. 56, Schinkelplatz 6) zu richten.
5. Die Resultate der Prüfung der eingegangenen Schriften durch fünf Preisrichter werden 1912 in der Meteorologischen Zeitschrift bekannt gegeben werden.

Der Vorsitzende der Deutschen Meteorologischen Gesellschaft.
Hellmann.

Translation.

The German Meteorological Society offers a prize of three thousand marks (M. 3,000) for the best discussion of the published observations secured on the dates of the International Ascents [with kites, sounding balloons, and manned balloons].

CONDITIONS.

1. The judges reserve the right to divide the amount of the prize among two or more contestants, if they feel justified in so doing.
2. Contestants may be of any nationality.
3. The essays or memoirs submitted in competition may be written in German, English, or French. The manuscript must

be legibly written, on one side of the sheet only, and signed with an anonymous motto. The paper must be accompanied by a sealed envelop bearing the motto on the outside, and containing a slip of paper with the name and residence of the competitor.

4. The competition will close December 31, 1911. The manuscripts should be sent [by registered mail] to the following address:

Geheime Regierungsrat Professor Dr. G. Hellman,
Schinkelplatz 6, Berlin, W. 56., Germany.

5. The memoirs submitted will be examined by five judges and their decision will be announced during 1912 in the pages of the Meteorologische Zeitschrift.

Signed: Hellmann,
President German Meterological Society.

A CALIFORNIA CLOUDBURST.

By J. S. Douglas, San Emigdio Rancho, Kern Co., California.
[U. S. Geological Survey Press Bulletin, October 12, 1908.]

In the upper reaches of San Emigdio Canyon, Kern County, Cal., cloudbursts have at many places stript the mountain slopes bare of their forest cover and swept great trees and masses of rock many miles from their source. Just where the creek breaks from the hills is the hacienda of San Emigdio Rancho, and the superintendent of the rancho, J. S. Douglas, who has had ample opportunity to observe the cloudbursts, gave the following description to H. R. Johnson, of the United States Geological Survey.

The cloudburst * * * issued from Cloudburst Canyon into San Emigdio Canyon about 8 miles above this ranch house. I had been expecting the occurrence, as the premonitory signs had been very pronounced for two or three days previously, viz, immense masses of white snowy clouds in the forenoons, changing in color to inky blackness in the afternoons, with the accompaniment of thunder. The weather was sultry, with occasional gusts of cool wind rushing *down* the canyon, an unusual occurrence during the day in summer time.

Some time before [the wave of mud and water] made its appearance, probably fifteen minutes, its dull and heavy roar could be heard from up the canyon, quite distinct from and rising above all the other noises of the storm and reminding me of breakers against a rocky shore. As it issued from the narrow mouth of Cloudburst Canyon into the comparatively broad one of San Emigdio, it was accompanied by a cloud of dust occasioned by the breaking up of huge masses of dry soil torn from projecting points in its rush down the canyon.

Through the dust glimpses would be had of great piles of drift with an occasional tree turning end over end * * *.

After reaching the main canyon it spread to a width of probably 200 yards, and after descending about one-half mile came to a full stop, only to be succeeded in a few moments by another wave larger and swifter than the first. There was no dust about this or any of the succeeding waves, but immense masses of rock, many of which must have weighed several tons, were apparently dancing along, light as corks on the surface, being supported by the rocky mass beneath.

This wave extended about one-half mile farther down the canyon than the first, when it also came to a stop, having spread to the full width of the canyon (about one-fourth mile here).

In a few moments another wave of mud swept by, followed by others at intervals of a few minutes, each succeeding wave getting thinner and traveling with greater velocity than the preceding ones, until finally in about half an hour it was mud no longer, but a steady rush of a yellow foaming torrent, at first probably 100 yards wide in the main canyon, gradually reducing its width and increasing its depth and swiftness as it washed out a channel in the soft mud.

In answer to your question as to the distance and size of rocks moved by cloudbursts, I will give you a description of one which lies on the bank of the creek close to this house. It is a sandstone bowlder which has come from 7 miles above and as near as it can be measured, owing to its irregular shape, gives the following dimensions: Height 8 feet, length 16 feet, width 12 feet. On the plains (the San Joaquin Valley) about 5 miles east of here, in sec. 22, T. 11 N., R. 21 W., several masses much larger than this can be seen. These were brought down the Pleito Canyon by cloudbursts.

Commenting on this description Mr. Johnson says:

The interesting point about the cloudburst described above is its ebb and swing. It has been further learned that the first wave which brings down the coarsest débris often forms a dam at or near the canyon's entrance. It is as a result of the impact between the later waves and

this débris dam that the greatest damage usually occurs, since the breaking of the dam at its weakest point usually results in the formation of new deep gulches in unexpected places, down which the liberated water and sludge rush toward the flatter marginal slopes of the fan, dividing and again dividing into smaller, less well-defined channels as they go. So far as observed, the end point of these cloudbursts is to be found in the thin irregular flows of mud left upon the lower slopes of the fans. These are in some places thick enough to obliterate the low bunchy grasses across which they have spread, and are characterized by a homogeneous, regularly cracked surface and an even, fine grain. Such thin, irregular mud beds are known by the well diggers of the region as "slickens."

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Librarian.

The following have been selected from among the titles of books recently received, as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies. Most of them can be lent for a limited time to officials and employees who make application for them. Anonymous publications are indicated by a ——.

[Aiginetos, Demetrios.] Ἀιγινήτος, Δημήτριος.
Τὸ κλίμα τῆς Ἑλλάδος. Ἐν Ἀθήναις. 1908. 2 v. 8°.

Angström, Knut.
...Einige fundamentale Sätze betreffs der Absorption und der Absorptionsspektrum der Gase. Uppsala. 1908. 13 p. 8°. (Archiv. für matematik, astronomi och fysik... Band 4, n:o 30.)

Astrophysical journal.
A general index. Chicago. 1908. 133 p. 8°.

Austria. Hydrographischer Dienst.
Jahrbuch... 13. Jahrgang. 1905. Wien. 1907. f°.

Behre, Otto.
Das Klima von Berlin. Eine meteorologisch-hygienische Untersuchung. Berlin. 1908. 159 p. 8°.

Bendel, Johann.
Wetterpropheten. Regensburg. 1904. 166 p. 8°. (Naturwissenschaftliche Jugend- und Volksbibliothek. 7 Bändchen.)

Canada. Department of the interior.
Canada's fertile northland... Ottawa. 1907. 139 p. 4°.
Maps. Canada's fertile northland. Ottawa. 1907. 5 maps.

Ciofalo, Michele.
Il clima di Termini dedotto dalle osservazioni meteorologiche del periodo 1880-1906. Termini. 1907. 72 p. f°.

Climate and health [of Sao Paulo].
In The state of Sao Paulo, Brazil. Statistics and general information, 1903. Department of agriculture, commerce, and public works of the state of Sao Paulo (Brazil). Sao Paulo. 1904. p. 12-18. 12°.

Contreras, Juan N.
Meteorologia practica. Nuevos metodos de prediccion. 2 parts. Mexico. 1907, 1902. 328, 54 p. 8°. 12°.

Crelle, A. L.
Dr. A. L. Crelle's Rechentafeln... Neue Ausgabe. Berlin. 1907. n. p. f°.

Dairen (South Manchuria). Meteorological observatory.
Report of the meteorological observations made at the Japanese meteorological stations in Manchuria. 1906. Dairen. [1908.] v. p. f°.

Fairbanks, Harold W.
The great earthquake rift of California. *In* Bulletin of the California physical geography club. Oct., 1907. Oakland. p. 1-8.

Ficker, Heinz v.
Zur Meteorologie von West-Turkestan. Wien. 1908. 35 p. f°. (Besonders abgedruckt aus dem 81. Bande der Denkschriften der mathematisch-naturwissenschaftlichen Klasse der Kaiserlichen Akademie der Wissenschaften.)

Findeisen, F.
Praktische Anleitung zur Herstellung einfacher Gebäude-Blitzableiter. 2d ed. Berlin. 1907. vi, 126 p. 8°.

Freybe, Otto.
...Klima- und Witterungskunde. Hannover. 1908. iv, 71 p. 12°. (Bibliothek der gesamten Landwirtschaft. Hrsg. von der Karl Steinbrück. 10. Band.)

Geographisches Jahrbuch.
31. Band, 1908. Gotha. 1908. ix, 493 p. 8°.

Gerdien, H.
...Untersuchungen über die atmosphärischen radioaktiven Induktionen. Berlin. 1907. 75 p. 4°. (Abhandlungen der Königlichen Gesellschaft der Wissenschaften zu Göttingen. Mathematisch-physikalische Klasse. Neue Folge. Band 5. Nro. 5.)

Great Britain. Meteorological committee.
3d annual report. London. 1908. 164 p. 8°.

Greim, G.
Schätzung der mittleren Niederschlagshöhe im Grossherzogtum Hessen im Jahre 1905 und Vergleichung der Niederschlagshöhen des Grossherzogtum im Jahrfünft 1901-5. Darmstadt. 1906. p. 59-64. 8°. (S.-A. Notizbl. Ver. Erdk. 4 Folge. Heft 27. 1906.)

Hellman, G[ustav].
...Meteorologische Volksbücher. Ein Beitrag zur Geschichte der Meteorologie und zur Kulturgeschichte. Berlin. 1895. 68 p. 4°. (Sammlung populärer Schriften herausgegeben von der Gesellschaft Urania zu Berlin. no. 8.)

Hesse. Grossherzogliches hydrographisches Bureau.
Deutsches meteorologisches Jahrbuch 1907. Darmstadt. 1908. 59 p. f°.

Klengel, Friedrich.
Die Niederschlagsverhältnisse von Deutsch-Südwestafrika. Leipzig. 1908. 72 p. 8°.

Kienast, Hermann.
Das Klima von Königsberg i. Pr. Teil. 3. Der jährliche Gang der Lufttemperatur, dargestellt auf Grund der Beobachtungen aus den Jahren 1848-1906. Königsberg. 1907. 45 p. f°.

McAdie, Alexander G.
Frost, snow, and dew. First paper. *In* Sunset magazine. San Francisco. Feb., 1908. p. 336-338.
Earthquake weather. *In* Bulletin of the California physical geography club. Oakland. Oct., 1907. p. 8-9.

Mainka, C.
Kurze Uebersicht über die modernen Erdbeben-Instrumente und einige Winke für die Konstruktion solcher. Berlin. 1907. 32 p. 4°.
Ueber die neueren Arbeiten im Observatorium der Kaiserlichen Hauptstation für Erdbebenforschung in Strassburg i. Els. Haag. 1907. 11 p. 4°.

Maryland geological survey.
[General report.] v. 6, 1906. Baltimore. 1906. 578 p. 4°.

Mauritius. Royal Alfred observatory.
Annual report... 1907. n. p. 1908. 18 p. f°.

Mill, Hugh Robert.
British rainfall 1907. London. 1908. 100 [200] p. 8°.

New South Wales. Royal society.
Journal and proceedings... 1907. v. 41. Sydney. 1908. xii, 218, xxvi p. 8°.

Physikalische Verein.
Jahresbericht... 1906-7. Frankfurt am Main. 1908. 110 p. 8°.

Regulamento do Serviço meteorologico de S. Paulo.
In Boletim de agricultura. 9 sér. Maio N. 5. Anno de 1908. Sao Paulo. 1908. p. 381-385. 8°.

Roumania. Institutul meteorologic.
Buletinul lunar al observatiunilor meteorologice. Anul 15, 1906. Bucuresti. 1907. 252 p. f°.
Same. Anul 16, 1907. Bucuresti. 1908. 263 p. f°.

Saxony. Königliches sächsisches meteorologisches Institut.
Deutsches meteorologisches Jahrbuch. 1903. Dresden. 1908. 180 (94) p. f°.

Scheiner, J[ulius].
Populäre Astrophysik. Leipzig. 1908. vi, 718 p. 30 pl. 8°.

Schubert, Johannes.
Das Klima von Ostpreussen. Eberswalde. 1908. 18 p. 12°.
Landsee und Wald als klimatische Faktoren. Leipzig. 1908. p. 688-694. 8°. (Sonderabdruck aus den 13. Jahrgange der Geographischen Zeitschrift.)

Siam society.
Rainfall records of the kingdom of Siam. (Journal of the Siam society. v. 4, part 2.) Bangkok. 1907. [60] p. 8°.

Southern Rhodesia. Statist.
Report on meteorology. London. 1908. 24 p. f°.

Urriola, Ciro L.
Sur les variations de la température... Panama. 1908. 26 p. 8°.

Walter, A.
On the influence of forests on rainfall and the probable effect of "déboisement" on agriculture in Mauritius. Mauritius. 1908. 51 p. f°.

Wyoming climate.
In Cheyenne, Wyoming, the city of opportunity. Issued by the Industrial club of Cheyenne. Cheyenne. [1908.] p. 20-21. 12°.

Zöppritz, August.
Prognosen aus den Gestirnstellungen für das Jahr 1908. Stuttgart. [1908. 34 p.] 8°.

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Librarian.

The subjoined titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers or other communications bearing on meteorology or cognate

branches of science. This is not a complete index of the meteorological contents of all the journals from which it has been compiled; it shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau. Unsigned articles are indicated by a ——

American geographical society. Bulletin. New York. v. 40. September, 1908.

Huntington, Ellsworth. The climate of ancient Palestine. p. 513–522.

Science. New York. New series. v. 28. October 9, 1908.

Shaw, W. N. Address of the president to the mathematical and physical section of the British association for the advancement of science. p. 457–471.

Archives des sciences physiques et naturelles. Genève. Tome 26. 15 Septembre, 1908.

Ramsay, William. Les gaz inertes de l'atmosphére et leur dérivation de l'emanation des corps radioactifs. p. 240–262.

Nature. Paris. 36 année. 12 Septembre, 1908.

—— E. Mascart. p. 238–240. [With portrait.]

Revue néphologique. Mons. No. 32. Août 1908.

Leal Mariano. A propos d'un nouvel anémomètre enregistreur. p. 49–50.

Geographische Zeitschrift. Leipzig. 14 Jahrgang. September, 1908.

Mecking, Ludwig. Der heutige Stand der Geographie der Antarktis. II. Das Klima. p. 481–492.

Meteorologische Zeitschrift. Braunschweig. Band 25. September, 1908.

Obermayer, A. von. Zwanzig Jahre meteorologischer Beobachtungen auf dem Ben Nevis. p. 385–396.

Russeltvedt, Nils. Ein neues Haarhygrometer. [Illustrated.] p. 396–400.

Meissner, Otto. Die Luftbewegung in Potsdam (1894 bis 1900). p. 400–409.

—— A. Gockel über den Gehalt der Bodenluft an radioaktiver Emanation. p. 410–412.

Busch, Fr. Eine neue Störung der atmosphärischen Polarisation. p. 412–414.

Sch., E. Schubert, der Wasserhaushalt an der Erdoberfläche. [Review.] p. 415–416.

Heidke, P. Resultate der meteorologischen Beobachtungen zu Kwai (Usambara) in den Jahren 1897 bis 1902. p. 416–418.

—— Meteorologische Beobachtungen im arktischen Nordamerika auf Herschel Island 1905. p. 418–419.

Friesenhof, Gregor. Zur lokalen Entstehung der Zyklonen. p. 419–420.

H[ann], J[ulius]. Stündliche Intensität der Regen zu Batavia und Pasuruan. p. 422.

Maurer, Hans. Regenmengen im Nigergebiet. p. 423–425.

Siegel, Fr. Meteorologisches Observatorium erster Ordnung zu Curityba (Paraná). p. 426–427.

Little, C. Ueber eine Windstille Region in 3,000 bis 4,000 engl. Fuss Seehöhe in der kalten Jahreszeit in der Gegend von Calcutta. p. 427.

Hann, J. Regenfall zu Pernambuco (Recife). [Collected data, 1887–1906.] p. 429.

Physikalische Zeitschrift. Leipzig. 9. Jahrgang. 15 September, 1908.

Kaufmann, W. Leuchtende Wolke. [Includes photograph of sky glow, July 2, 1908]. p. 606–607.

Wetter. Berlin. 25. Jahrgang. September, 1908.

Grundmann, G. Ueber einen einfachen Gewitterregistrator mit dem Verbesserten Schreiberschen Nadelkohärer. [Illustrated.] p. 193–201.

Schulze, Paul. Ludwig Friedrich Kämtz. p. 201–203.

Joester, Karl. Die Föhnerscheinungen im Riesengebirge. p. 203–206.

Becke, L. von der. Die Ergebnisse meteorologischer Beobachtungen auf der Lloyds-Signalstation auf Kap Spartel für das Jahr 1907 in Monats-und Jahresmitteln. p. 209–211.

Freybe, Otto. Ein Vormittag an einer Wetterdienststelle. p. 213–216.

AN ANNOTATED BIBLIOGRAPHY OF EVAPORATION.

By MRS. GRACE J. LIVINGSTON. Dated Washington, D. C., January 8, 1908.

[Continued from the Monthly Weather Review, June, 1908.]

1782.

Eason, Alexander.

On the ascent of vapor. (1782.) Mem. lit. phil. soc., 1785, **1**:395–405.

1786.

Rosenthal, Gottfried Erich.

Ueber P. Cotte's Versuch die Stärke der Ausdünstungs im Rücksicht auf die Höhe und den Durchmesser der Gefässe die zum Maasse gebraucht werden. Mag. neu. Phys., 1786, **1** (pt. 4):142–54.

It is claimed that the law of differences, for evaporation from different vessels, which Cotte (1781) failed to find, is as follows: (1) dishes of like height and surface give like evaporation in the same time and place; (2) dishes of like height and unlike evaporating surfaces give the same evaporation if reckoned by depth, but different if by volume; (3) in the case of dishes of different heights, with like or unlike evaporating surfaces, the depth of water lost by evaporation is proportional to the square roots of their heights.

Williams, Samuel.

Experiments on evaporation, and meteorological observations made at Bradford, in New England, in 1772. Trans. Amer. phil. soc., 1786, **2**:118–41.

In experiments with evaporation from two small vessels, the amount lost from the one refilled every week was found to be greater than that from the dish which was refilled only once a month. A vessel floated in the Merrimac River during a calm, rainless week lost 0.15 in. by evaporation, while a similar vessel freely exposed in the open air lost 1.50 in. Evaporation was found to be greater from soil covered with vegetation than from an equal area of free water surface.

1787.

de Saint-Lazare, Bertholon.

De l'électricité des meteores. Paris. 1787. 2 v. 8vo.

In volume 2, p. 84–99, a chapter "Sur l'évaporation" proposes an electrical theory for explaining evaporation.

1788.

Cotte, P.

Mémoires sur la météorologie. Paris. 1788. 2 v. 4to.

Discounts (**1**:100) the influence of moonlight on evaporation. Reviews (**1**:175–265) experimental and theoretical investigations of various physicists, including Wallerius, Lambert, Musschenbroek, Van Swinden, Richmann, Kratzenstein, Hamberger, Homberg, Desaguliers, Franklin, Kames, Dobson, Achard, etc. Describes experiments as in 1781, to ascertain the influence of the diameter and height of the containing vessels upon the rate of evaporation. Describes (**1**:280) a simple evaporator used by Chevalier de la Mark. Discusses (**1**:480) the cooling effect of evaporation as demonstrated with the moistened bulb of a thermometer.

1789.

Saussure, H. B. de.

Col du Géant; expériences sur l'évaporation. Obs. phys., 1789, **34**:161–80. Translated in Jour. Phys., Leipsic, 1790, **1**:453–73. Reprinted in Voyages dans les Alpes. Geneva, 1779–96. 4 v. 4to.

Evaporation from a piece of moist linen stretched in a frame, was observed on the Col du Géant, where the air pressure is only 18 in. 9 lines, and at Geneva, Switzerland, where it is 27 in. 3 lines, with the result that "other things being equal, a lowering of the pressure of the air by approximately a third makes the quantity of evaporation more than twice as great." Deals also with the cooling effect produced by evaporation.

1790.

Deluc, John Andrew.

Seconde lettre à M. Delamétherie sur la chaleur, la liquefaction, et l'évaporation. Obs. phys., 1790, **36**:193–207. Translated in Jour. Phys., Leipsic, 1790, **2**:402–29.

Discusses theories to explain the process of evaporation. That of the solution of water by air is considered "a vague hypothesis without solid foundation and useless to explain the phenomenon." He maintains that evaporation proceeds from the union of fire with the molecules of the liquid.

Hube, J. M.

Ueber die Ausdünstung und ihre Wirkungen in der Atmosphäre. Leipsic. 1790. 2 v. in 1. 8vo.

Monge, Gaspard.

Sur la cause des principaux phénomènes de la météorologie. Ann. chim. phys., 1790, **5**:1–71.

The vesicular hypothesis of evaporation is rejected in favor of the theory of the solution of water vapor in the air, on the following grounds: (1) Air in absorbing water preserves its transparence, which could not happen if the water was merely suspended by some mechanical means; (2) the solvent power of air diminishes as the quantity of water dissolved increases, so that an actual saturation is reached; (3) the point of saturation varies with the temperature of the air, so that air saturated at a high temperature contains more water than air saturated at a lower temperature; (4) if air saturated with water is cooled it becomes supersaturated and abandons the water which its former higher temperature permitted it to retain. It is concluded that, since these circumstances ordinarily accompany all solutions and are generally regarded as characteristic of them, the absorption of water by air is the result of a true solution.

1791.

Deluc, J[ohn] A[ndrew].

Examen d'un mémoire de M. Monge, sur la cause des principaux phénomènes de la météorologie. Ann. chim. et phys., 1791, **8**:73–102. Translated in Jour. Phys. Leipsic, 1792, **6**:121–48.

It is maintained that Le Roy's experiments at Montpelier, which Monge (1790) accepted as decisive proof that evaporation is the solution of water in air, are better explained by considering fire as the sole agent.

Vassali-Eandi, A. M.

Esame delle teorie dei principali fenomeni della meteorologica del Sign. Monge, colle riflessione del Sign. ———. Biblioteca oltremontana. Turin. 1791.

1792.

Deluc, John Andrew.

On evaporation. Phil. trans., 1792, **82**:400–28. Also in Phil. trans., abridged, 1791–96, **17**:259–63. Translated in Jour. Phys. Leipsic, 1794, **8**:141–60, 293–302.

The fact that every liquid cools when it evaporates is considered a most decisive reason for the opinion that the dissolution of water, observed in the phenomenon of evaporation, results directly from the action of heat without the intervention of air. Hygrology is defined as the science of the causes of evaporation and the modifications of evaporated water. A discussion of hygrometry follows with the conclusion that the product of evaporation is always an expansible fluid which affects the manometer by pressure and the hygrometer by moisture, without any hitherto perceived influence from the presence or absence of air.

1793.

Dalton, John.

Meteorological observations and essays. London. 1793. p. xvi + 208. 8vo.

The process and circumstances promoting evaporation are described in Pt. 2, Essay 6, p. 132 *et seq.* Heat, dry air, and decreased pressure of the atmosphere upon the evaporating surface are emphasized. In the author's experiments, the rate of evaporation from water, "pretty much exposed to sun and wind," never exceeded 0.2 in. daily. In March the daily average was 0.033 in. It is considered probable that "the evaporation both from land and water, in the temperate and frigid zones, is not equal to the rain that al ls, even in summer."

Wistar, Caspar.

Experiments and observations on evaporation in cold air. Trans. Amer. phil. soc., 1793, **3**:125–33.

The author believes these experiments and observations support Deluc's theory, which ascribes the "smoking" of water to the passage of "heat" or "fire" from the moist body into the air around it, a process which does not depend "upon a positive degree of heat, but merely an excess of it in the moist body when compared with the air to which it is exposed."

1794.

Senff, Erdmann Friedrich.

Beobachtungen und Versuche über den Erfolg verschiedener Abdünstungs-Arten des süsses Wassers aus Salz-Soolen auf Salzwerken nebst Folgerungen daraus. (1775, May–Oct.) Jour. Phys. Leipsic, 1794, **8**:84–94, 357–66.

Evaporation from water freely exposed from May to October, inclusive, in a small tin vessel amounted to 24 inches, 13/24 line; the rainfall for the same time being 9 inches, 2¼ lines. Experiments made with aqueous salt solutions of different strengths showed that the strongest solutions lost least by evaporation. From a table giving the results of similar experiments under different temperatures, it may be calculated that the ratios between evaporation rates from different solutions approach each other as the temperature increases.

Zylius, J. D. O.

Ueber Herrn Deluc's Lehre von der Verdünstung und dem Regen. Jour. Phys., Leipsic, 1794, **8**:51–64.

After discussing the nature of evaporation the author concludes that it is an actual solution of water in air.

1799.

Wistar, Caspar.

Experiments on evaporation. Trans. Amer. phil. soc., 1799, **4**:72-3, Also in Med. repos., 1801, **4**:179–80.

His conclusions are similar to those in his paper of 1793.

1800.

•**Heller, Egidius.**

Ueber den Einfluss des Sonnenlichts auf die Verdünstung des Wassers. Ann. Phys., 1800, **4**:210–22.

Describes observations which tend to show that, the temperature of the air remaining constant, evaporation varies with the amount and strength of sunlight falling on the evaporating surface.

1801.

Dalton, John.

New theory of the constitution of mixed aeriform fluids, and particularly of the atmosphere. Jour. nat. phil. chem., 1801, **5**:241–4.

Proposes "four suppositions in respect to the affections of the particles of one elastic fluid toward those of another," and adopts the idea that "particles of one elastic fluid may possess no repulsive (or attractive) power, or be perfectly inelastic with regard to the particles of another; and consequently, the mutual action of such fluids, or the action of the particles of one fluid on those of another, will be subject to the laws of inelastic bodies." Two mixed fluids, "whatever their specific gravity may be, will immediately, or in a short time, be intimately diffused thru each other, in such a manner that the density of each considered abstractedly, will be uniform thruout." The particles "will diffuse themselves thru any given space, occupied by a very rare medium, in the same manner as they would do in a vacuum, each particle being impelled as far as possible from its neighboring particle; only the diffusion of each may be a little retarded by the other." "The vapor of water and of every other fluid which does not unite chemically with the azotic and oxygenous gases of the atmosphere, and without any regard to its pressure on the surface of the earth, being totally uninfluenced by any other pressure than that arising from the weight of their own particles: in short, each vapor, in regard to pressure, is in the same circumstance as if it were the only elastic fluid constituting the atmosphere." "Tho-e gases and vapors press separately on the surface of the earth; and any one of them may be withdrawn or another added to the number, without materially disturbing the rest, or in any way affecting their density. The above doctrine necessarily requires the force of vapor from any fluid to depend solely upon temperature, and consequently to be the same in any gas as in an exhausted receiver."

Hermstaedt, S. F.

Vesuche über den Einfluss der Elektricität auf die Verdünstung und meteorologische Folgerungen daraus. Ann. Phys., 1801, **7**:501–11.

A mass of air, of known volume at the freezing point, was enclosed over a water seal and heated to 100° (F. ?). The air expanded a certain amount and, upon being recooled to freezing, resumed its original volume. The same air was then subjected to the action of electricity from an electrical machine, cooled, heated, and recooled, as before, when the air appeared to have been permanently expanded. The author concludes that this permanent expansion resulted from the permanent elasticity given to some of the water vapor by the electricity.

Mons, J. B. v.

Censura commentarii a Wieglebo nuper editi, cui titulus: de vaporis aquei in aerem conversione. Brussels. 1801. 4to. Also, Chem. Ann., 1801, **1**:76-84, 129–43, 185–200.

Parrott, G. F.

Grundzüge zu einer neuen Theorie der Ausdünstung und des Niederschlags des Wassers in der Atmosphäre. Mag. f. neu Zustand Naturk., 1801, **3**:1–57.

An extensive series of experiments, with deductions from his own and others' work, results in an elaborate theory of the phenomenon of evaporation, and of cloud and rain formation. The theory is based on several erroneous conceptions, *e. g.*, that evaporation from ice is oxidation.

Parrott, G. F.

Vermischte physikalische Bemerkungen. Ann. Phys., 1801, **10**:166–218.

A distinction is assumed between physical and chemical evaporation; the former is supposed to be dependent on the temperature and the latter on the oxygen content of the air.

1802.

Böckmann, Carl Wilhelm.

Einige Vorläufige Bemerkungen über Herrn Prof. Parrott's neue Theorie der Verdünstung und des Niederschlags des Wassers in der Atmosphäre. Ann. Phys. Leipsic, 1802, **11**:66–88.

The author doubts the validity of the experimental evidence furnished by Parrott (1801) and the theoretical conclusions of his paper are controverted.

Dalton, John.

Experimental essays on the constitution of mixed gases; on the force of steam or vapor from water and other liquids in different temperatures, both in a Torricellian vacuum and in air; on evaporation and on the expansion of gases by heat. Mem. lit. phil. soc., 1802, **5**:535–602. Translated in Bull. soc. philom., 1803, **3**:189–91; also in Ann. Phys., 1803, **12**:310–18.

The theory of the chemical solution of water vapor in air is declared to be complex and attended with difficulties, such as that it can exist independently in a vacuum at any temperature. Adopts a theory which admits of a distinct elastic vapor in the atmosphere at all temperatures and uncombined with either of the principal constituent gases. Some general laws of evaporation established by others are exprest.

The objects of the essay are: (1) to determine the effect of temperature on the rate of evaporation; (2) to determine the relative evaporability of different fluids; (3) to find a rule for ascertaining the quantity and effect of water vapor previously in the air; (4) from these and other facts to obtain a true theory of evaporation. A table shows the force of vapor and the full evaporating power of every degree of temperature from 20° to 85° exprest in grains of water raised per minute from a vessel 6 inches in diameter, supposing there were no vapor already in the atmosphere. He determined, by weighing, the amount of water evaporated from two tin dishes, one 6 inches in diameter and ¼ inch deep, the other 8 inches in diameter and ¾ inch deep; and found that, for high temperatures, the rate of evaporation was exactly proportional to the vapor tension. To test this principle for low temperatures it was found necessary to consider the partial pressure of the water vapor actually existing in the atmosphere. It is concluded that the evaporating force is equal to the vapor tension at the temperature of the water, diminished by that at the temperature of the air. The same principle was found to hold below the freezing point. He refers to Saussure's experimental determinations of the amount of elasticity imparted to dry air by imbibition of aqueous vapor, and shows that the results coincide rather closely with his own. Dalton, however, considers that Saussure placed too much confidence in his [hair?] hygrometer, and that his observations seem to corroborate the theory that aqueous vapor is a distinct elastic fluid rather than a chemical solution of water in air as he supposed.

Dalton, John.

Experiments and observations made to determine whether the quantity of rain and dew is equal to the quantity of water carried off by rivers, and raised by evaporation; with an inquiry into the origin of springs. Mem. lit. phil. soc., 1802, **5**:346–72. Translated in Ann. Phys., 1803, **15**:249–78.

The annual rainfall over England and Wales is estimated at 31 inches, and dew-fall at 5 inches, while the runoff of the rivers accounts for only 13 inches, leaving 23 inches to be accounted for by evaporation. An experiment was made with a cylindrical tinned iron vessel, 10 inches in diameter and 3 feet deep, with two tubes inserted in one side and turned downward (for collecting surplus water in bottles), one tube near the bottom, the other an inch from the top. This cylinder was filled with gravel and sand to the depth of a few inches, then with fresh soil, and the whole was sunk in the ground, the side bearing the tubes being exposed. The layer of soil was kept saturated with water. Three years' observations (1796–8) in which the annual average rainfall was found to be 33.55 inches, showed the evaporation from soil to be 25.14 inches, and that from a free water surface, 44.43 inches. Hence, he concluded that: (1) under the above circumstances, 25 inches of the rainfall and the 5 inches estimated for dew, making a total of 30 inches, are evaporated annually; (2) the quantity of evaporation increases with the rainfall, but not proportionally; (3) there is, apparently, no great difference between the amount of evaporation from bare earth with sufficient depth of soil, and that from ground covered with vegetation. The difference between the amount calculated as available for evaporation and the observed amount, is taken to support the theory that the earth derives a supply of water from some subterranean reservoir. Reasons, however, are given for considering the observed evaporation as perhaps greater than the actual, and it is finally concluded that "the rain and dew of this country are equivalent to the quantity of water carried off by evaporation and the rivers."

Dalton, John.

New theory of the constitution of mixed gases elucidated. Phil. mag., 1802, **14**:169–73. Also Jour. nat. phil. chem., 1802, **3** (n. s.):267–71. Translated in Ann. Phys., 1803, **12**:438–45.

A further explanation of the same theories announced in 1801.

Kirwan, Richard.

Of the variations of the atmosphere. Trans. roy. Irish acad., 1802, **8**:278–330.

In the chapter on evaporation, the causes of evaporation are said to be "heat, affinity to atmospheric air, agitation, electricity, and light." Discusses Saussure's experiments with a card supersaturated with moisture, which lost 2 grains in a quarter of an hour when electrified, while another, not electrified, lost 1½ grains. Reprints Saussure's table (1789) comparing evaporation at different altitudes.

1803.

Cotte, L.

Observations météorologiques faites à Montmorenci près Paris pendant l'année 5 (1797) de la République. Mém. inst. nat. sci. et arts, 1803, **4**:261–5.

The amount of evaporation for the year 1797 is reported as 18 inches, with a rainfall of 26 inches, 6.8 lines. (Fr. ?.)

Dalton, John.
Eine neue Theorie über die Beschaffenheit gemischter luftförmiger Flüssigkeiten, besonders der atmosphärischen Luft [aus Jour. nat. phil. chem. **5**:241]. Ann. Phys., 1803, **15**:385–95.

Translation of Dalton, 1801.

Dalton, John.
Versuche über die Expansivkraft der Dämpfe von Wasser und andern Flüssigkeiten, sowohl im luftleeren Räume als in der Luft [aus Mem. lit. phil. soc., **5**:550, et seq.]. Ann. Phys., 1803, **15**:1–24.

Dalton, John.
Versuche über die Verdünstung [aus Mem. lit. phil. soc., **5**:574, et seq.]. Ann. Phys., 1803, **15**:121–43.

Dalton, John.
Sur l'expansibilité des gaz mélangés avec les vapeurs, extraite et traduit du Repertory of Arts par Houry. Jour. mines, 1803, **14**:33–6.

Gilbert, Ludwig Wilhelm.
Einige Bemerkungen zu Dalton's Untersuchungen über Verdünstung. Ann. Phys., 1803, **15**:144–68.

Discusses the theories of evaporation held by Dalton, Saussure, Deluc, etc.

Hermstaedt, S. F.
Observations sur une méthode d'évaporation spontanée de l'eau des puits salins à la température de l'atmosphère; considérations sur le degré d'utilité des applications qu'on pourrait faire dans les salines du Royaume, et recherches sur les causes physiques qui concourrent pour produire cette évaporation. Mém. acad. sci., 1803, (—):91–104. Also Samml. Deut. Abh. Akad., **6**:63–73. Also Neu. allg. Jour. Chem., 1804, **2**:317–34.

Parrott, G. F.
Ueber Herrn Wrede's Bemerkungen gegen seine hygrologische Theorie. Ann. Phys., 1803, **13**:244–50.

Answer to Wrede's criticisms in connection with the theories announced in the papers of 1801. (See Wrede, 1803.)

Parrott, G. F.
Ueber den Phosphor, das Phosphor-Oxygenometer, und einige hygrologische Versuche, in Beziehung auf Herrn Prof. Böckmann's vorläufige Bemerkungen über diese Gegenstände. Ann. Phys., 1803, **13**:174–207.

Answer to Böckmann's criticisms of his theories. (See Böckmann, 1802.)

Wrede, E. F. K.
Kritische Bemerkungen über einige neuere Hypothesen in der Hygrologie, besonders über Parrott's Theorie der Ausdünstung und Niederschlagung des Wassers in der atmosphärischen Luft. Ann. Phys., 1803, **12**:319–52.

Discussion and criticism of Parrott's (1801) theory of chemical and physical evaporation, Hube's (1790) vesicular system, etc.

1804.

Soldner, Johann von.
Ueber das allgemeine Gesetz für Expansivkraft des Wasserdampfes durch Wärme, nach Dalton's Versuchen; nebst einer Anwendung dieses Gesetzes auf das Verdünsten der Flüssigkeiten. Ann. Phys., 1804, **17**:44–81.

A mathematical discussion of the law of increase of vapor tension for every degree of rise in temperature, and the application of this law to the evaporation of liquids. Discusses Dalton's law and develops a formula by which, from the elastic force and the observed evaporation of any liquid at its boiling point, the evaporation at any other temperature may be determined.

1805.

Blanchet, F.
On the vapor which rises from the surface of the River St. Lawrence during the severe cold of winter. Med. repos., 1805, **3**:154–5.

Mayer, Johann Tobias.
Lehrbuch über die physische Astronomie, Theorie der Erde und Meteorologie. Göttingen. 1805.

Discusses, p. 168–81, the influence of different temperatures of both the evaporating surface and the surrounding air, on the rate of evaporation; also the influence of sunlight and of different surfaces and depths of the evaporating mass. Defines the atmometer as a glass vessel filled with water, the evaporation from which is measured by a graduated scale or by weighing. For the best results it should be floated on the surface of some large body of water. Discusses the seasonal variations in the amount evaporated.

1807.

Flauguerges, Honoré.
Mémoire sur le rapport de l'évaporation spontanée de l'eau avec la chaleur. Jour. phys., Paris, 1807, **70**:446–53. Translated in Jour. nat. phil. chem., 1810, **27**:17–24.

Experiments to determine whether evaporation is proportional to the extent of surface exposed, or is dependent on some function of the other dimensions of the body of water, as Musschenbroek and Cotte asserted, proved that it is simply proportional to the surface exposed. Experiments to determine the effect of heat seemed to show that, while the degrees of temperature vary in arithmetical progression, the corresponding losses by evaporation vary in geometrical progression. The following formula shows the relation:

$$y = (4.4) \cdot (2.7182818)^{\frac{x}{11.0527301}},$$

in which x represents the degree of temperature on Deluc's thermometer and y the corresponding evaporation, exprest in parts of the scale used. For the evaporation in millimeters y must be multiplied by $\frac{27.07}{196}$, or we may substitute 0.6268843 for the coefficient 4.4 in the equation.

Soldner, Johann v.
Nachtrag zu der Abhandlung über das allgemeine Gesetz der Expansivkraft der Wasserdämpfe. Ann. Phys., 1807, **25**:411–39.

This is a continuation of his paper of 1804, and a discussion of Dalton's law of vapor tension.

1809.

Cotte, Louis.
Mémoire sur l'évaporation. Jour. phys., Paris, 1809, **68**:434–41.

1810.

Cotte, Louis.
Mémoire sur l'évaporation. Jour. phys., Paris, 1810, **70**:206–8.

D'Aubuisson de Voisan, J. F.
Notice sur la quantité d'eau en vapeur contenue dans l'atmosphère, sur la diminution de densité qui en resulte, et sur le produit de l'évaporation en un temps déterminé. Jour. mines, 1810, **27**:411–9.

In discussing the laws of vapor tension and density he derives a formula for the diminution of the density of air due to water vapor. The annual average weight of the vapor contained in a cubic meter of air is given as 9.0 grams, and the annual average diminution of density is 0.0029, the density of air being 1.0. A formula is derived for the quantity of water, Q, evaporated at temperatures between 60° and 100°: $Q = n\phi'$, where ϕ' is the elastic force of vapor at the temperature, and n is a constant to be determined by experiment. Tables show the monthly evaporation calculated for Geneva, that observed at the Observatoire de Paris in 1809, and the evaporation at different elevations as observed by Humboldt, Gay-Lussac, and Saussure.

Fischer, Ernst Gottfried.
Darstellung und Kritik der Verdünstungslehre nach den neuesten besonders den Daltonschen Versuchen. Berlin. 1810. 8vo.

Flauguerges, Honoré.
Mémoire sur le rapport de l'évaporation de l'eau avec l'humidité de l'air. Jour. phys., Paris, 1810, **70**:157–67. Translated in Jour. nat. phil. chem., 1812, **32**:330–9.

In an experiment to ascertain the influence of humidity on evaporation, air was dried by exposure to lime for three weeks. A vessel was then filled with this air by displacement of sand and it was found that, at a constant temperature, the rate of evaporation from a water surface exposed therein decreased in geometrical progression with the increase in humidity. The author concludes that the rate of evaporation is proportional to the amount of additional water vapor needed for saturation; and points out that this agreement with the law of solution of solids in liquids appears to confirm the hypothesis of Musschenbroek and Le Roy that evaporation of water is merely a solution of this substance in air. Following Saussure, the author determined the absolute humidity of saturated air at 65° F. and announced formulas for finding the point of saturation at any temperature, and for calculating the evaporation at any temperature and humidity. The latter formula is:

$$E = \left[(2.72)^{\frac{x}{11.05}} - \frac{z}{12}\right] (0.34\,\text{lines}),$$

where E is the evaporation in lines in 24 hours at the temperature x of De Luc's thermometer, and in air which contains z cubic lines of water in the cubic foot.

1812.

Carradori, Gioachino.
Dell' evaporazione del ghiaccio e della neve. Gior. fis. chim., 1812, **5**:203–8.

Upholds the theory of the affinity of air and water, and that evaporation is a combination of molecules of water with "la materia del calorico termico," i. e., the "element" of fire. When water is changed to ice, the affinity of cohesion or aggregation, is changed to chemical affinity or composition. More force is required to evaporate ice than water, because of this chemical affinity.

1813.

Leslie, John.
A short account of experiments and instruments depending on the relations of air to heat and moisture. Edinburgh. 1813. p. 178. 1 pl. (See Brandes, 1825.)

Discusses the cooling produced by evaporation, and the different methods of cooling water, etc., employed by people living in hot countries. Describes a differential thermometer used as a hygrometer, consisting of two glass air chambers connected by a tube containing sulfuric acid (H_2SO_4). His atmometer is a thin ball of porous earthenware, 2 or 3 inches in diameter, with a small neck which is cemented to the lower end of a long and rather wide closed tube, graduated so that each division corresponds to an internal section equal to a film of liquid that would cover the outer surface of the ball to the thickness of 1/1000th part of an inch. In still air the indications of the atmometer and hygrometer were found to have the following relation: 1/20 of a hygrometer degree = 1/1000 inch of evaporation.

1814.

Vassali-Eandi, A. M.
Saggio di un trattato di meteorologia, memoria ricevuta li 19 Dic., 1814. Mem. soc. ital. sci., **17**:230–55.

A general account of meteorological instruments which includes a description of an atmidometer (p. 242).

1816.

Bellani, Angelo.
Riflessioni critiche intorna all' evaporazione, colla descrizione di un nuovo atmidmometro. Gior. fis. chim., 1816, **9**:102–14, 188–206, 250–62, 417–46. Abstract in Bibl. ital., no. 6, Milan, 1816. Translation of abstract in Bibl. univers., 1816, **2**:153–9.

Discussion of work by Leslie and others concerning the cold produced during evaporation. Reviews general laws and theories of evaporation as explained by Saussure, Lavoisier, Cotte, Gay-Lussac, Dalton, Flauguerges, etc. Holds with Kirwan and Richmann that the temperature of the air in contact with the water has considerable influence on the

rate of evaporation. According as the temperature of the air is equal to, warmer than, or colder than the water the evaporation will be slow in the first case, nothing in the second, and rapid in the third. Quotes from ancient writers on the subject.

Thilo, Ludwig.
Uber das Verhältniss der Ausdünstung auf dem Meere und auf dem Lande. Arch. Med. Aarau, 1816, **1**:250–6.

1818.

Schön.
Die Witterungskunde in ihren Grundlage. Würzburg. 1818.

Discusses methods of measuring evaporation and experiments of Musschenbroek (see Cotte, 1774, and Saussure, 1789).

1820.

Anderson, Adam
Description of a new atmometer. Edinb. phil. jour., 1820, **2**:64–7. Translated in Jour. Chem. Phys., 1820, **28**:326–8.

Presents objections to the ordinary shallow dish for ascertaining the "dissolving power" of the air, and also to Leslie's porous bulb atmometer. The latter is objectionable on account of the impossibility of using it in frosty weather and during showers, when rain is forced into the interior.

Anderson proposes an instrument which consists of an hermetically sealed system of glass bulbs and tubes containing only alcohol and its vapor, and so arranged that when the two bulbs are at different temperatures the liquid contained in the one bulb will be condensed in a second bulb and collected in a graduated tube attached to the latter. The condensing bulb is covered with wet silk or paper and evaporation therefrom cools the condenser to a temperature below that of the other bulb. The amount of alcohol collected in the graduated tube is a measure of the amount of evaporation during the corresponding time period. The apparatus is inverted to bring the distilled alcohol again into the original bulb. A scale was made for the instrument by comparing its operation with the amount of water lost from a free water surface.

Bellani, Angelo.
Descrizione di un nuovo atmidometro per servire di continuazione e fine alle riflessioni critiche intorno all' evaporazione. Glor. fis. chim., 1820, **3** (decade 2):166–77. Also reprinted, Pavia, 1820.

The evaporating surface of this instrument consists of a porous clay disc which closes the mouth of a metallic vessel connected thru a stop-cock with a second vessel which has a hinged cover. The first vessel is also connected laterally with a horizontal graduated glass tube of small bore having its free end open to the air. The second vessel is so placed that when filled its water level is not higher than that of the clay disc, but is considerably higher than the graduated tube. The whole system having been filled with distilled water and the stop-cock closed, evaporation from the clay surface removes water from the primary vessel and air enters the open end of the glass tube, forcing the meniscus backward at a rate which indicates the rate of evaporation. When the water meniscus approaches the attached end of the glass tube the tube is refilled by opening the stop-cock between the two vessels.

1823.

Brandes, Heinrich Wilhelm.
Uebersetze aus d. Engl. ins Deutsche u. commentirte: Leslie—Kurzer Bericht von Versuche u. Instrumenten, die sich auf d. Verhalten d. Luft zur Wärme u. Feuchtigkeit beziehen. Leipsic. 1823. 8vo.
(See Leslie, 1813.)

Vassali-Eandi, A. M.
Descrizione di un nuovo atmidometro per misurare l'evaporazione dell' acqua, del ghiaccio, e di altri corpe a varie temperature. Ricevuta Aprile 29, 1823. Mem. soc. ital. sci., 1823, **19**:347–53.

The author describes a sensitive balance with a thermometer suspended from one end of its beam and dipping into the cup containing the substance whose evaporation is to be studied. He emphasizes the fact that two atmometers to be compared must be exposed under exactly similar conditions.

Vassali-Eandi, A. M.
Nota sopra le straordinarie variazioni del barometro, sopra il massimo grado di caldo e di freddo, la quantitá della pioggia, della neve, e dell' evaporazione, che si osservarono nel 1821, con alcuni cenni sopra le qualitá dell' annata. Mem. r. accad. Torino, 1823, **27**:xli–xliv.

The evaporation for the last nine months of the year 1821 was observed to be 47 inches, 5.3 lines, while the rainfall for the entire year was 36 inches, 11.9 lines.

Walker, Ezekiel.
Philosophical essays selected from the originals printed in the philosophical journals between the years 1802 and 1817. London. 1823. 8vo.

1824.

Daniell, John Frederic.
On evaporation. Quart. jour. sci., 1824, **17**:46–61. Also in Notiz. Geb. Nat. u. Heilk., 1825, **10**:col. 65–73. See also Boston jour. phil. arts, 1824–5, **2**.39–50.

Distinguishes three conditions under which evaporation occurs: (1) When the temperature of the evaporating liquid is such as to produce vapor having a pressure equal to that of the atmosphere, that is, when it boils. (2) When the temperature of the liquid is above that of the surrounding air but below its own boiling point. (3) When the temperature is below that of the atmosphere. Considers (3) at some length. Describes experiments on evaporation from water in almost absolutely dry air (under the bell-jar with sulfuric acid), also under varying pressures (by means of the air-pump). In the latter case there was an increase in evaporation with decrease in pressure, and under yet greater rarefaction the water froze.

1825.

Bostock, John.
On evaporation. (Letter to J. F. Daniell.) Quart. jour. sci., 1825, **18**:312–7. See also Notiz. Geb. Nat. u. Heilk., 1825, **10**:col. 84–5.

The quantity of water evaporated from a free water surface of small dimensions was determined by weighings at short intervals, accompanied by observations on the temperature of the air and water, barometric readings, direction of the wind, and general weather observations. The tabulated results are followed by some discussion of the relative evaporation at different seasons of the year, under different barometric pressure, different temperatures, etc.

Prinsep, J.
Description of a pluviometer and an evaporometer constructed at Benares. Asiatic researches, 1825, **15**: (app.), xiii–xv.

He describes and figures an atmometer consisting of an exposed cup connected with a graduated tube of smaller diameter and at a lower level, this tube being supplied with a piston for driving water into the cup. The instrument is operated by first filling the tube to the standard level and then forcing water by means of the piston, into the cup from which it is in like manner withdrawn to standard level at the end of a given time, note being made of the difference in the position of the piston at the beginning and end of the operation. The ratio between the diameters of the cup and the tube gives the magnification of the observed loss.

1826.

Schübler, Gustav.
Beobachtungen über die Verdünstung des Eises. Naturw. Abh., 1826, **1**:211–8. Also general conclusions in Quart. jour. sci., 1829, **1**:187.

A table of observations of evaporation from January 1 to February 28 shows the amount lost from a surface of ice or water, the average temperature of the period, the average relative humidity, and the average height of the barometer at 55° F. During certain dry, cold weather the evaporation from ice in twenty-four hours was twice as great as from an equal surface of water in the middle of February during mild, cloudy weather. From these observations it is concluded that "evaporation of ice is far more considerable than has been supposed, and that in certain natural circumstances it may even surpass that of water."

1827.

Hällström, G. G.
De hygrometrico aëris statu tempore aestivo anni 1826 observato Aboa. (Diss. acad.) Aboae. (Abo, Finland), 1827. 4to.

Hällström, G. G.
Observationes circa evaporationem hieme proxime elapsa institutae. (Diss. acad.) Aboae. (Åbo, Finland), 1827. 4to.

Klaproth.
Sur l'évaporation de l'eau à une haute température. Ann. chem. et phys., 1827, **35**:325–9.

Experiments with water drops on a very hot metal surface much above the boiling point of water, showed that the hotter the metal the less rapid was evaporation.

Meikle, Henry.
Remarks and experiments relating to hygrometers and evaporation. Edinb. new phil. jour., 1827, **2**:22–32.

He presents some experiments and formulas connected with the use of the hygrometer as a measure of evaporation.

Pouillet.
Mémoire sur l'électricité des fluides élastiques, et sur une des causes de l'électricité de l'atmosphère. (Lu à l'acad. des sci., le 30 Mai, 1825.) Ann. chim. et phys., 1827, **35**:401–20.

The author describes experiments which show that the electricity accompanying vaporization is due to the more or less intense chemical action which takes place between the elements of the liquid and the vessel which contains it. This fact is considered proof that the electricity of the atmosphere can not have the origin which Volta is said to have assigned to it, i. e.. the natural evaporation from land and sea.

1828.

Schrön, Hermann Ludwig Friedrich.
Beschreibung, Gebrauch und Eigenschaften des Hyetometers und Atmometers. Met. Jahrb. Jena, 1828, **6**:135–44.

1829.

——— Experiments on evaporation made in the vicinity of Calcutta. Glen. sci., 1829, **1**:286–90.

In connection with the manufacture of salt at Ballyaghat near Calcutta, the rate of evaporation from enclosed tanks of from 150,000 to 850,000 square feet area and 3 to 4.5 inches depth, was studied. The experiments being on such a large scale many sources of error were necessarily considered. After discussing and allowing for these, the conclusion is reached that the evaporation rate for this place is at least as follows: January, 3 inches; February, 5 inches; March, 7 inches; April, 9 inches; and May, 9 inches.

——— Experiments on evaporation performed at Vera Cruz in 1818–20. Glen. Sci., 1829, **1**:335–7.

These experiments on evaporation from water are compared with those near Calcutta, described in the preceding paper. Variations are shown in the amount of evaporation according to the different dishes used and their exposure. To this is subjoined a note giving the results of four years' observations [by the Editor ?] of the evaporation at Benares [Oriental Magazine, 1827, (?)], as follows:

	December and January.	March.	April.	July.
Mean temperature........degrees F..	62.3	79.4	91.1	84.4
Depression of wet bulb........do	6	16.3	20.3	2.0
Monthly evaporation........inches..	2.55	7.3	13.9	3.0

Dalton's formula applied to these figures would give about one and one-eighth times the amount of evaporation actually observed.

1830.

Anderson, Adam.
Evaporation. Edinb. Encyc,, 1830, **9**:217–21.

The author describes in detail Dalton's experiments on the evaporation from soil and water (Dalton, 1805, 2d title]. He cites Duluc, 1792; Dalton, 1802; Saussure, 1783; Murray on Hygrometry in Murray's Chemistry, vol. 2, p. 705; and Doctor Wells on Dew. The latter attempted to show that the ice formed in porous pans at Bombay, is not due to evaporation, but to radiation, that the water, may, in fact, be increased by dew.

Dove, Heinrich Wilhelm.
Notiz über die Verdampfungskälte. Ann. Phys., Leipsic, 1830, **19**:356.

The cooling effect produced by evaporation from a thermometer bulb moistened with ether is shown to be accentuated when the ether vapor is absorbed by sulfuric acid as it is formed.

Muncke, G. W.
Geographie nebst Atmosphärologie. Heidelberg. 1830. p. 446-9.

Review of the literature of "atmospherology," including the work of Saussure, Gregory, Musschenbroek, Richmann, Wallerius, Lambert, Cotte, Bellani, and others.

Schübler. Gustav.
Grösse der wässerigen (Ausdünstung) im Jahre 1828. Jour. Chem. Phys., 1830, **58** (J. 28):208-9.

1831.

Holbrook, Josiah.
Evaporation. Scientific Tracts, Boston, 1831, **1**:151-4, 257-80.

General discussion of evaporation and the cold produced by the process.

Schübler, G.
Grundsätze der Meteorologie in näherer Beziehung auf Deutschlands Klima. Leipsic. 1831. p. 65-75.

General discussion of the methods of measuring, and the factors influencing the rate of evaporation. A table compares the annual evaporations at Rome, Rochelle, Manchester, Würzburg Tübingen, etc. The effects of temperature and wind on evaporation are also summarized in separate tables. The author then discusses the application of the amount of evaporation to the determination of the dew-point and the moisture content of the air. Studies of evaporation from soil and plants are reviewed and a table shows the relation, at different seasons, of the evaporation from the soil to that from water surfaces. Another table compares the daily evaporation from grass with that from water, and includes average temperatures and wind directions. The grass is seen to have evaporated much more than the free water surface.

1832.

Bellani, Angelo.
Sul moto molecolare dei solidi, e sul limite dell' evaporazione. Poligrafo, 1832, **10**:161-70.

Ideler, Iulius Ludovicus.
Meteorologia veterum Græcorum et Romanorum. Berlin. 1832. p. 87-95.

Cites references to evaporation in the writings of Hippocratus, Aristotle, etc. They were apparently aware of the cooling due to evaporation through porous vessels containing water, etc.

1836.

Bischof, K. G. C.
Einige physikalische und chemische Beobachtungen in den Schweizer Alpen.—1. Ueber die Verdünstungskälte in der Nähe von Wasserfällen. Ann. Phys. and Chem., 1836, **37**:259-61.

Observations of temperature in the immediate neighborhood of waterfalls and at some distance from them show the cooling effect produced on the surrounding air by the evaporation of the mist.

Kämtz, Ludwig Friedrich.
Lehrbuch der Meteorologie. Leipsic. 1836. p. 344.

Gives a general discussion of the subject.

Murphy, Patrick.
Meteorology. London. 1836. p. 82-91.

Ridicules the theory of the solution of water vapor in air, upholding that evaporation is an electrical decomposition of water into oxygen and hydrogen. Quotes Bertholon de Saint-Lazare (1787) at some length in support of this view.

1837.

Howard, Luke.
Seven lectures on Meteorology. Pontefract, England. 1837. p. 69-72.

Describes the process of evaporation and concludes that, on the whole, the amount evaporated must be equal to the rainfall, "the one being the source of the other." Affirms the rate of evaporation to be dependent on temperature and wind velocity and states that a common rate per day from a freely exposed water surface is 1/100 to 1/10 inch in winter, 2/10 to 3/10 inch in summer. A table of the monthly evaporation near London from 1807 to 1815, shows an average total for the year of 30.75 inches.

He considers that the best instrument for measuring evaporation is a "shallow, metallic cistern" provided with a scale of three diagonals, engraved on an oblong plate of glass, the divisions of the scale to be 1/10 inch apart, and the descent in proportion of 1/100th to each division.

Klee, Franz.
Prüfung der Lehre von Druck der Luft, nebst einer neuen Theorie über die Verdünstung und Bildung der Niederschläge in der Atmosphäre. Mainz. 1837. 8vo.

Pouillet.
Éléments de physique expérimentale et de météorologie. Paris. 1837. 2 vols. 8vo. See **1**:261, 291, 303-6, 555 et seq.; and **2**:629-30.

Pouillet supports a theory of evaporation agreeing in the main with that of Dalton, [Dalton, 1801 and 1802, 1st title]. The rate of evaporation depends, not only on the movement of the air, but on the difference between the pressure of the vapor forming and that of the vapor already formed in the air. He quotes Dalton's law. Evaporation is also proportional to the extent of surface exposed. In discussing the cold produced by evaporation, the author states that 1 grain of water vapor, formed by evaporation, has absorbed a quantity of latent heat capable of raising 500 grains of water 1° in temperature. In volume 2 it is maintained that atmospheric electricity results from the chemical segregations accompanying evaporation from the surface of the earth.

1838.

Espy, J. P.
Experiments on spontaneous evaporation. Franklin inst. jour., 1838, **22**:74-5.

He describes simple experiments with evaporation of water from porous pots and tumblers sunk in the ground, from moist earth, and from wet towels in motion and at rest; and gives the accompanying temperatures of the air and the dew-point.

Leslie, J.
Treatises on various subjeces of natural and chemical philosophy. Encyclopedia Britannica. Edinburgh. 1838.

In the chapter on Meteorology, p. 402-537, the porous clay atmometer is described as in his paper of 1813. A general review of the theoretical side of the subject includes the vesicular theory held by Halley, Leibnitz, Musschenbroek, Desaguliers, Kratzenstein; and the advance made in 1750 by Hamberger, who attributed evaporation to a real solution of moisture in the air, and by Le Roy who followed along the same lines. The experiments of Wallerius, Musschenbroek, Richmann, Saussure, and Kirwan are given critical attention. It is maintained that the full cooling effect on the wet-bulb thermometer may be obtained without the whirling practised by Saussure.

1840.

Kämtz, Ludwig Friedrich.
Vorlesungen über Meteorologie. Halle, 1840. p. 69, 392.

A general discussion.

Muncke, G. W.
Verdünstung. Gehler's Physikalisches Wörterbuch. Leipsic. 1840. **9** (pt. 3):1720-50.

The article Verdünstung gives a survey of the literature of the subject up to 1840, including the work of Dalton, Schübler, and others.

1842.

Dausse.
De la pluie et de l'influence des forêts sur les cours d'eau. Ann. ponts chauss., 1842, **3** (2): 184-209, 197-201.

In discussing the effects of evaporation and its immense rôle in nature, the author presents tables of rainfall and evaporation in France, together with the average monthly height of the Seine. The object is to show that the greatest evaporation follows close upon the greatest rainfall, but that the highest stage of the Seine occurs when the rainfall and evaporation are least. It is calculated that evaporation reduced the volume of water in the Seine from 7 to 3, or more than half, and that the reduction would not have been as great if the banks had been forested instead of being bare as was the case at that time.

Rowell, G. A.
On the retardation of evaporation by electric insulation. Proc. Ashmol. soc., 1841, **23**:7. Also Phil. mag., 1842, **20**:45-6.

Experiments on the relative evaporation of water from an insulated vessel and an uninsulated one, showed an excess of evaporation from the latter of 14 dwts., 9 grains. The author belives that if complete insulation could be maintained, no evaporation would take place at moderate temperatures.

Saigey.
Petite physique du globe. Paris. 1842. p. 108-12.

The yearly evaporation at Paris from circular dishes, 30 or 60 centimeters in diameter, and 10 or 20 centimeters deep, is stated to be about 800 mm. when the dishes are half filled with water.

1844.

Baily, J.
On the Isthmus between the Lake of Grenada and the Pacific. Jour. roy. geog. soc., 1844, **14**:127-9.

An incidental remark in this article states that, according to various calculations, the average annual evaporation in inter-tropical climates amounts to 39 inches.

Liénard.
Sur le mélange de l'eau de mer à l'atmosphère. Mém. soc. agr., Bayeux, 1844, **2**:289-90.

1845.

Daniell, John Frederic.
Elements of Meteorology. London. 1845. 2 v. Volume 2, p. 25, 66, 220, 236.

According to this author, "the hygrometer may be applied to indicate the force and quantity of evaporation." Refers to Dalton's law that the quantity of water evaporated in a given time, bears a definite relation to the force of vapor at the same temperature. A table shows the full evaporating force of every degree of temperature from 18° to 85° F. Discusses the conditions and laws of evaporation from water and soil.

Laidlay, T. W.
Observations on the rate of evaporation on the open sea; with a description of an instrument used for indicating its amount. Jour. Asiat. soc. Bengal, 1845, **14**:213-6. Also abstracted by Blanford, 1877.

Leslie's atmometer is described and criticized as lacking simplicity of construction and use. An instrument of his own invention consists of a small glass tube, closed at both ends, at the lower end by means of a plug of some porous substance as wood. The tube is filled with distilled water and attached to a scale upon which the amount lost from the tube by evaporation from the surface of the plug may be observed. Observations were made with this instrument, hung in the shade but freely exposed to the wind, on board ship between England and Calcutta. The daily average,, from lat. 37° 15′ S. to lat. 24° 25′ S., was 0.398 inches, and thru the Tropics 0.809 inches. A table of von Humboldt's results of observations in similar regions with Deluc's hair hygrometer, reduced by d'Aubuisson's formula, gives a much smaller rate. Laidlay explains the discrepancies by the fact that Deluc's hygrometer takes no account of the important agency of the wind. Laidlay's instrument, suspended in the shade on an open verandah in Calcutta, gave a daily average evaporation of 0.507 inches for the year.

Parkes, Josiah.
On the quantity of rain compared with the quantity of water evaporated from or filtered thru soil; with some remarks on drainage. Jour. roy. agr. soc., 1845, **5** (1st ser.): 146-58.

The author describes experiments by John Dickinson, to determine the percentages of rainfall which percolate thru the soil or evaporate from its surface. Besides a rain gage, he employed for this purpose a cylinder filled with soil and sunk in the ground, this cylinder having a false perforated bottom and a receptacle beneath for collecting the percolation water. This lower receptacle communicated by a small tube with a second vertical cylinder

below the level of the other, the diameter of the second bearing some convenient ratio of that of the first. The percolation water is measured by means of a graduated stem borne on a float in the second cylinder. The evaporation includes that due to the plant growth on the surface of the soil. The results of eight years' observations, 1836–43, show the annual evaporation to be 57.5 per cent of the rainfall, or 15.3 inches. Other estimates are quoted.

Regnault, Victor.

Etudes sur l'hygrométrie. Compt. rend., 1845, **20**:1127–66, 1220–37. Also Ann. chim. et phys., 1845, **15** (3d ser.):129–236. Translated from Comptes rendus in Ann. Phys. und Chem., 1845, **65**:135–58, 321–60. Also Sci. mem., 1846, **4**:606–60.

The first part (p. 1128–66) contains: (1) a table of the varying tensions of water vapor in saturated air at a series of different temperatures; (2) a table of the varying densities of water vapor in saturated air at different temperatures; (3) a table of similar densities in air of different degrees of humidity below saturation. The second part (p. 1220–37) describes methods of determining the relative humidity of the air: (1) the chemical method; (2) that founded on the changes occurring in hygroscopic materials; (3) that of the condensation hygrometer; (4) that founded on the indications of the wet and dry-bulb thermometers. This is followed by formulas and tables.

Rowell, G. A.

On the phenomena of evaporation, the formation and suspension of clouds, etc. Edinb. new phil. jour., 1845, **38**:50–6. Reviewed in Franklin inst. jour., 1847, **44**:340–3.

The author is of the opinion that vaporization is produced by an increase in the electrical charge of the water particles and that condensation is due to a decrease in or removal of this charge. Thus evaporation is considered a phenomenon of static electricity. This theory is elaborated at length and a number of meteorological phenomena are considered from this standpoint.

1846.

Ludlow.

Observations on evaporation made at the Red Hills, near Madras, in 1844. Madras jour. lit. sci., 1846, **13**:87–93. Also quoted by Blanford, 1877.

By careful experiments he compared the rate of evaporation from an evaporator floated on the surface of a large tank, with that from an evaporator on land some distance from the tank, and found one-fifth less evaporation from the tank exposure than from the land exposure during the hottest months of the year. The results show a gradual increase in the ratio between the two, but this is at least partially accounted for by the fact that the depth of the water in the tank diminished about 6 feet from April 1 to August 20. He concludes that "depth is important in such reservoirs, the amount of evaporation not only increasing with surface but inversely as the depth." The rainfall during the period was 8 inches, the total fall in the water level of the tank was 83 inches, and the evaporation 53 inches, so that only three-eighths of the amount disappearing was available for irrigation. Tables of results, including temperature observations, etc., are given.

1847.

Daubrée, G. A.

Observations sur la quantité de chaleur annuellement employée à évaporer de l'eau à la surface du globe, et sur la puissance dynamique des eaux courantes des continents. Abstract by the author, Compt. rend., 1847, **24**:534–50. German translation in Ann. Phys. und Chem., 1847, **71** (3d ser.):173–5.

In calculating the amount of heat annually consumed in evaporation, the total evaporation is considered equal to the total rainfall on the surface of the earth, which is estimated as 703,435 cubic kilometers, equivalent to a layer of water having a uniform depth of 1.379 meters over the entire earth. This amount of evaporation consumes nearly one-third of the heat annually received from the sun. The total energy of evaporation is estimated as more than 1,800 times that manifested by the flowing waters of the earth, the latter approximating 9,000 million horse-power.

Glaisher, James.

Hygrometrical tables, containing temperature of the dew-point; the elastic force and weight of vapor; degree of humidity; weight of air, etc.; corresponding to all readings of the dry- and wet-bulb thermometers between 10° and 90° [F.]. With directions for using, and explanation of the theory and uses of the dry- and wet-bulb thermometers. London. 1847. First edition. 8vo.

Babinet, J.

Note sur un atmidoscope. Compt. rend., 1848, **27**:529–30.

He describes an instrument somewhat similar to Leslie's (1813), in which evaporation takes place from the surface of a reservoir of porous clay filled with water. The reservoir is supplied from a vertical tube connected therewith and at a lower level, and the evaporation is measured by the lowering of the water level in the latter. The advantage is claimed for this instrument over the ordinary hygrometer, of being influenced by the movement of the air and of registering the integrated effect from the beginning of the experiment.

Cartillon, C.

Synthèse de quelques météores dépendents du phénomène de l'évaporation de l'eau. Trans. Roy. soc. arts, sci., Mauritius, 1848, **2**:97–118.

Rowell, G. A.

On the cause of evaporation, rain, hail-stones, and the winds of the temperate regions. Rpt. Brit. assoc. adv. sci., 1847. (Notices p. 41.)

Repeats his hypothesis expounded in 1845.

1848.

Vallés, F.

Projet de desséchement et d'irrigation du lac de Grand-Lieu. Ann. ponts chauss., 1848, **16**:158–251.

Dissusses, p. 226–31, the relative intensity of evaporation. Results obtained from 1782–1801 by Calandrelli and Conti are quoted from de Prouy's work on the Pontine marshes (?). A table gives the annual average evaporation as 2.362 meters and the ratios according to the seasons. The daily evaporation at Nantes is calculated at 0.005 meters.

1849.

Buist, G.

On the saltness of the Red Sea. Trans. Bombay geog. soc., 1849, **9**:38–48.

It is stated incidentally (p. 39), that the temperature of the surface of the Red Sea varies from 65° to 85° F., that the difference between the wet-bulb and dry-bulb is from 25° to 40° F., and that the average evaporation at Aden is 8 feet per year.

Charnock, J. H.

On suiting the depth of drainage to the circumstances of the soil. Jour. roy. agr. soc., 1849, **10**:507–19.

In connection with percolation experiments, from 1842 to 1846 inclusive, the following average annual data are presented in tabular form: (1) rainfall, 24.6 inches; (2) evaporation from a water surface freely exposed to sun and wind, 35.05 inches; (3) evaporation from water shaded from sun but exposed to wind, 23.35 inches; (4) evaporation from drained soil, 19.76 inches; (5) evaporation from saturated soil, 32.68 inches. Dalton's observations (1802, 2d title) in similar experiments are quoted, together with those of Dickinson (Parkes, 1845).

Harting, Pieter.

Drie nieuwe physische wertingen-Hygrometer, Drijfbalans, en Atmometer of Verdampingsmeter. Utr. Anteek. prov. genoots., 1849, (—):6–18.

Norton, W. A.

On the diurnal variations in the declination of the magnetic needle, and in the intensities of the horizontal and vertical magnetic forces. Amer. jour. sci., 1849, **8**;350–64. Abstracted by Ramsay, 1884.

He attributes the daily decrease in the horizontal force of the magnetic needle, between 4 and 10 a. m., to the evaporation of the dew or rain that has fallen during the night.

Schübler, G.

Grundsätze der Meteorologie in näherer Beziehung auf Deutschlands Klima. Leipsic. 1831. First Edition. Neu Bearbeitet [2d Edition] von G. A. Jahn. Leipsic. 1849.

Evaporation is discust on p. 72–80.

1850.

Kunzek, August.

Lehrbuch der Meterologie. Vienna. 1850.

Gives definitions of Verdünstung and Verdampfung (p. 95), and discussion of evaporation in general (p. 96).

Lenz, H. F. E.

Beitrag zur Bestimmung der in St. Petersburg verdünstenden Wassermenge, Mél. phys. et chim., 1850, **1**:226–38. Also Bul. acad. imp. sci., 1851, **9**:col. 86–94.

The loss of weight by evaporation from two small brass dishes of water, was observed during the winter of 1849–50. The apparent disagreements between the evaporation rate on the one hand, and the temperature and humidity on the other, are explained by wind conditions, the importance of which as a factor influencing evaporation is emphasized. Comparisons of the evaporation from ice with that from freezing water, show the latter to have the higher rate. A curve of bi-hourly readings of evaporation is seen to follow the daily march of temperature. He also compares the diurnal and nocturnal rates of evaporation.

Vallés, F.

Note sur une exception remarquable que présente la mesure de l'évaporation naturelle à Saint-Jeane-de-Losne, Dijon, Pouilly et La Roche-sur-Yonne. Ann. ponts chauss., 1850, **20**:383–93. Abstract in Rogers Field, 1869.

According to this paper hydraulic engineers have generally considered the amount of evaporation in France to be much greater than the rainfall. Seven years' observations on the Canal de Bourgogne at the places mentioned show, however, that only once did the evaporation exceed the rainfall, and that the average evaporation is less than half what it had hitherto been considered. (See Tarbé, 1852, for similar results.)

1851.

Charié-Marsaines.

Sur les travaux de la rigole dérivée de l'Yonne pour l'alimentation du point de partage du canal du Nivernais. Ann. ponts chauss., 1851, 1 (3d. ser.):289–333.

In Note A, p. 320–4, are described observations on evaporation from the Languedoc canal for the 320 days that the navigation of the canal annually lasts, and the result showed a loss of 0.812 meter. The results obtained by Halley, Sedileau, and Cotte are quoted, and the ratio between the evaporation at different seasons of the year, as estimated by Vallés and Cotte, is discust.

Espy, James.

Third Report on Meteorology to the Secretary of the Navy. Washington, 1851.

He reports, p. 19, experiments on the relative lowering of temperature produced by the evaporation of sea water and fresh water from the bulb of a thermometer. An equal depression was thought to have been observed in both cases, wherefore it is assumed that evaporation from sea water is the same as evaporation from fresh water under the same circumstances.

Miller, J. F.

On the relation of the air and evaporation temperatures to the temperature of the dew-point, as determined by Mr. Glaisher's hygrometrical tables founded on the factors deduced from six-hourly observations made at the Royal Observatory, Greenwich. Phil. trans., 1851,(—):141–8. Notice in Phil. Mag., 1 (4): 168.

A comparison of dew-points determined by the use of Daniell's hygrometer and the wet- and dry-bulb thermometers proved the extreme accuracy of Glaisher's tables. Experiments on the evaporation of water in a small copper vessel exposed to sun and wind, but partially sheltered at night and in wet weather, showed an annual average for the six years, 1843–8, of 30.011 inches with an average annual rainfall of 45.25 inches.

A MERCURIAL BAROGRAPH OF HIGH PRECISION.

By Professor CHARLES F. MARVIN. Dated Washington, D. C., September 4, 1908.

The pressure of the air and its variations constitute some of the most important factors in meteorology and the dynamics of the earth's atmosphere, and many excellent instruments have been devised and employed for many years to measure and continuously record these data.

The literature of the subject is already very full and should be consulted by readers seeking complete information relating to such instruments. The object of the present paper is to describe in detail a new form of siphon barograph designed by the writer some years ago, and which has since operated with such highly successful and accurate results as to prove the instrument distinctly superior to any of the numerous forms[1] that have been extensively tested at the Central Office of the Weather Bureau in Washington, D. C.

COMPENSATED SIPHON BAROGRAPH, MARVIN SYSTEM.

This instrument is illustrated in figs. 1 and 3 and belongs to that class in which the record is made mechanically without the interposition of any clock-work or electric mechanisms to overcome friction, etc. To secure satisfactory records on a highly magnified scale by this method, it is indispensable that the friction involved in writing the magnified record be removed to the last degree. Experience has demonstrated that this has been accomplished in the arrangement described, and this instrument proves to be exceedingly accurate and far more reliable than any of the types in which indirect registration is employed. This results from the fact that in the latter class of apparatus the clock and electrical mechanisms which effect the registration act in a certain sense indirectly and themselves introduce certain variable errors. Moreover, the weakening of batteries or the failure of electric mechanisms from time to time, result in interruptions in the record that do not occur in the system of direct mechanical registration employed in the new instrument.

Compensated siphon.

The barometer of this instrument is a special form of siphon quite clearly shown in fig. 1, and with dimensions marked in fig. 2. The long and short branches consist of simple, straight tubes. These are narrowed down at the lower ends where they are fitted into the upturned branches of the bend, or U. The tubes, in fact, form hollow stoppers carefully fitted and ground in. The tops of the U above the ground joints are provided with bells, or cups, of ample size, which have a lip formation on one side. This three-piece construction enables the barometer to be filled in the most satisfactory manner, but more especially the siphon, after being once filled, can be assembled or dismantled and transported without loss of the vacuum. The mercury in the open leg of the siphon in the course of time becomes more or less fouled with oxidation, the accumulation of dust, etc. The construction described permits of removing the short branch of the siphon at any time with very little trouble. The tube and excess of mercury can then be thoroly cleaned and replaced. The following details concerning the mounting of the siphon will explain this part of the instrument.

Filling and installing the siphon.—The ordinary siphon tube made in one piece of any considerable size, is very difficult to fill and secure a good vacuum, and it can not then be easily cleaned or transported. The present three-piece construction overcomes these difficulties very perfectly and requires only that the long straight branch be carefully filled. This may be done by almost any of the methods described hereafter, but the air-pump method (see fig. 7) is undoubtedly the best.

[1] A description of several of these instruments will be found in the Annual Report of the Chief Signal Officer, 1887, Part 2, and in U. S. Weather Bureau Circular F, Instrument Division, 3d ed., 1908.

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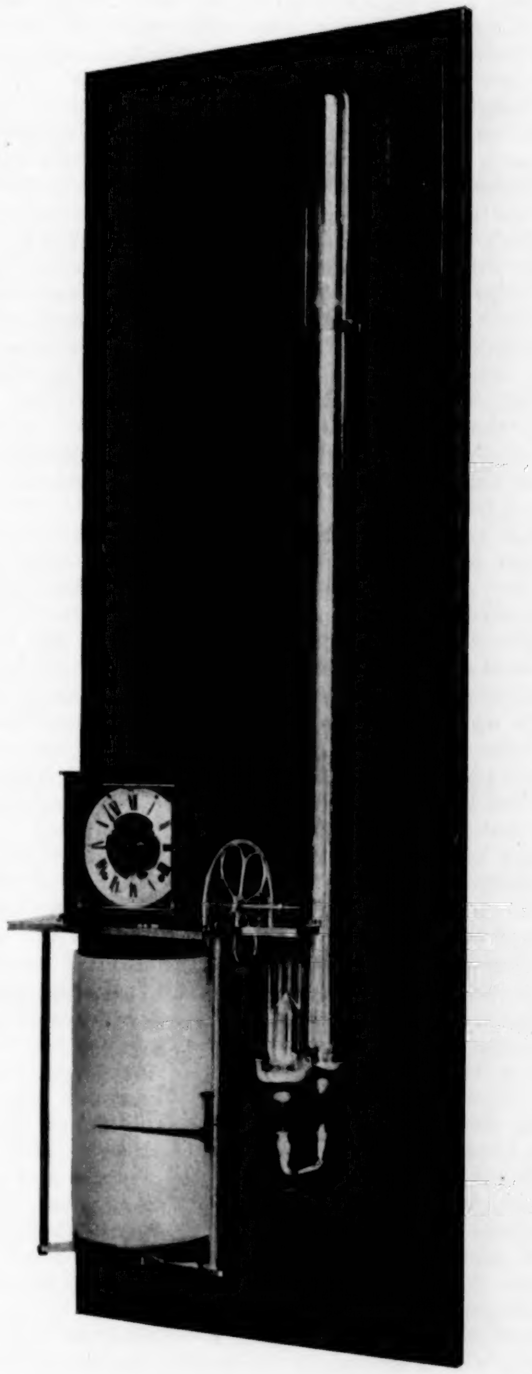

FIG. 1.—General view of compensated siphon barograph, Marvin system. Cover removed.

When the siphon is to be installed it will be well to prepare the ground joints by the application of a little lubricant, such as vaseline, tallow, or, if available, special stop-cock lubricant, very sparingly rubbed over the external surfaces of the tubes. A little pure mercury is next filtered into the bend or U-shaped section. Little air bubbles, if any appear, should be excluded by tilting the tube and causing the mercury to flow about in a manner that will accomplish this result. When the mercury covers the ground surfaces the short branch of the siphon should be carefully inserted and the whole secured to the instrument in the manner provided. More pure mercury is now added to the open cup until it is filled nearly to the brim. As some mercury is likely to be spilled in some of the subsequent

operations, it is a good plan to support a clean porcelain or glass photographer's tray close underneath the plate supporting the bend. This will serve to catch small excesses that may escape.

The long branch of the siphon, filled to overflowing with clean mercury, may now be lifted and, while the open end is temporarily closed firmly with the finger tip, the tube is carefully inclined in a manner that will permit the finger and point to be dipt below the free surface of mercury in the cup. Still supporting the weight of the heavy tube so that the end does not bear with undue pressure upon the parts of the cup, the whole is carefully and slowly brought into a vertical position. When the elevation of the tube has reached the point at which the mercury begins to leave the top of the tube, an assistant should be in readiness to catch in a suitable vessel (a dry, clean, drinking glass will answer very well) the excess of mercury that overflows from the open cup.

The heavy tube must be fully supported until quite vertical and the end only then inserted into the ground joint and rotated a little as it is faced to the front.

Certain precautions must be observed thruout the operations just described. (1) The tip end of the tube must not, under any circumstances, be lifted out of the mercury after the finger is removed, and especially not after the mercury has begun to flow out of the tube. (2) After the flow of mercury has started the elevation of the tube must be slow and gradual, otherwise the column of mercury tends to oscillate or surge up and down, and may threaten to uncover the point of the tube in the cup. (3) Any lowering of the tube causes the mercury to recede into the vacuum, and will empty the cup unless the supply is kept up by pouring back some of the excess that has already overflowed.

Having finally seated the long branch, some of the excess of mercury must be restored to the siphon and the level brought up to the proper point in the open leg. At the completion of these operations one of the cups of the bend is full to overflowing with mercury, and the other is nearly or quite empty. Some of the mercury in the full cup can easily be removed by splashing it out into a cup held to receive it and using a piece of card or an ivory paper-folder for the purpose. A little mercury may be added to the empty cup.

To clean the mercury.—When the glass and mercury in the open leg become soiled with prolonged use, all that is necessary to clean these parts is, first to remove the float, then carefully loosen the short branch of the siphon and permit the excess of mercury to overflow into a clean glass. When thus emptied the open branch may be removed and thoroly washt, cleaned, and replaced. Most of the dirt will come away with the glass tube, but the mercury may easily be filtered and replaced perfectly clean and bright.

To dismantle the siphon.—If it is desired to take down the siphon it is first necessary to remove the short branch, carefully collecting the excess of mercury, and then, after separating the ground joint of the long arm, the latter is slowly inclined while an assistant steadily pours mercury into the open cups to supply what recedes into the vacuum. When the tube is entirely filled the finger may be slipt over the open end while submerged in the mercury and the whole tube removed.

Temperature compensation of the siphon.

By giving the siphon barometer proper dimensions the influence of temperature can be eliminated for all practical purposes. The compensation operates so that temperature changes which affect the whole instrument uniformly, produce no sensible change in the level of the mercury in the short or open branch of the siphon. The actual difference of level of mercury in the two branches will, of course, be affected by temperatures in the usual way, but not the absolute position of the surface in the open leg. Since all measurements are made only on this surface in many forms of mercurial barograph, it is very desirable to realize in the design of such instruments this condition of automatic compensation for temperature.

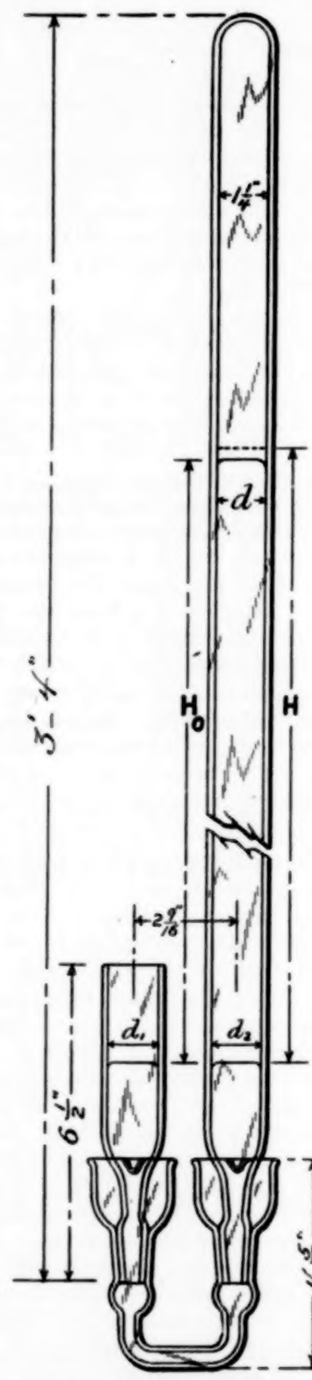

FIG. 2.—Dimensions of the Marvin compensated siphon barograph.

The physical principle utilized for this purpose is found in the different rates of expansion of mercury and glass or whatever material is used for the tube or envelop for the mercury. If the coefficient of expansion of the envelop were zero the mercury would rise slightly in the open leg with rise of temperature, and vice versa. As the theory of this temperature compensation is not stated in the ordinary text-books of physics and meteorology, and in fact does not appear to be widely known, it seems worth while to present it here

briefly. The theory was developed by Prof. G. W. Hough[2] in 1862, and later by Goulier.[3]

Let m = cubical expansion of mercury per unit temperature.
g = cubical expansion of glass per unit temperature.
V_0 = volume of mercury in instrument at temperature t_0.
d = diameter of tube at top of column in vacuum.
H_0 = height of column at temperature t_0.
H = height of column at temperature t.
d_1 and d_2 = diameter of the two branches of the siphon at the level of the top of the column in the open branch.

We assume that the pressure remains constant, therefore the barometric column for a change of temperature must change its length by an amount represented by the expression $m(t-t_0)H_0$, otherwise its hydrostatic pressure will be altered; that is,

$$H - H_0 = m(t-t_0)H_0.$$

Neglecting small quantities of a second order of magnitude, the volumetric increase in the barometric column will be the expression

$$\tfrac{1}{4}\pi d^2 m(t-t_0)H_0,$$

which is the change necessary to preserve hydrostatic equilibrium.

Now, the actual apparent change in the volume of mercury in the tube will depend upon the differential expansion of mercury and glass, and is given by the expression:

$$V_0(m-g)(t-t_0).$$

When this increase is just equal to that necessary to preserve hydrostatic equilibrium, all the expansion will seem to take place in the vacuum chamber, and no change will occur in the level of the mercury in the open leg. To realize this condition, we have:

$$V_0(m-g)(t-t_0) = \tfrac{1}{4}\pi d^2 m(t-t_0)H_0,$$

whence

$$V_0 = \frac{\pi d^2 H_0}{4}\,\frac{m}{m-g}.$$

The expression

$$\frac{\pi d^2 H_0}{4}$$

is the volume of the barometric column supposing the diameter is the same thruout as at the top.

The cubical coefficient of expansion of mercury, m, is a very definite quantity and, for barometric work, may be taken to be .0001010 per degree Fahrenheit. The expansion of glass is much smaller and varies considerably, ranging, according to Regnault's measurements, from .0000145 for common white tubing to .0000118 for the hard French and crystal tubes. That is to say, the whole volume of mercury in a siphon for compensation must be about

$$V_0 = 1.168\frac{\pi d^2 H_0}{4}$$

if the siphon is made of common tube glass,
or

$$V_0 = 1.132\frac{\pi d^2 H_0}{4}$$

if it is made of French crystal glass.

No great exactness is necessary in determining the volume V_0. It will suffice to assume H_0 equal to the mean barometric pressure at the place of observation, and the total volume of mercury should be about 17 per cent more than requisite to fill a column of height H_0 and diameter d.

If the bend of the siphon is of wide bore, the open leg and bend must be very short, e. g., $30 \times 0.17 = 5.1$ inches, otherwise V_0 will be too large. For this reason, as well as for convenience of construction, the bend is best made of smaller diameter than the main tube, as shown in the illustration.

If the long arm of the siphon is of full width only in its upper portion, and the remainder of the tube is of slender cross section, then the whole volume of mercury will be deficient unless the bend is long or of wide bore which are not desirable features of construction.

The theory given above takes account only of the influence of temperature on the mercury and glass tube. The effects that result from changes in the mechanisms for transmitting and inscribing the record, as described later, and for holding the glass barometer tube itself, all require consideration; but fortunately these are in the main so small, especially when considered in relation to the highly magnified scale on which the record is inscribed, that they may be neglected. In any case they can be incorporated with the mercury effect so that by adding or removing small amounts a certain total volume, V_0, of mercury at temperature t_0 may be employed, such that all effects of temperature on the whole apparatus will be automatically compensated.

If the siphon is not compensated, then the volume of mercury at temperature t_0 is V_1, which in general will be greater than V_0, but may be less; and a small correction will be required, the amount of which will be simply the apparent expansion of the excess of mercury occupying the bend and short leg of the siphon. This expansion may be imagined to simply lift the whole column of mercury a small amount, Δh.

The volumetric expansion will be

$$(V_1 - V_0)(m-g)(t-t_0)$$

and the rise of mercury, Δh, is given by the expression

$$\frac{\pi}{4}(d_1^2 + d_2^2)\,\Delta h = (V_1 - V_0)(m-g)(t-t_0).$$

In general, d_1 and d_2 will be made sensibly equal, and in fact equal to d, hence:

$$\Delta h = 2(V_1 - V_0)\frac{(m-g)(t-t_0)}{\pi d^2}.$$

Let y be the amount by which the mercury in the open leg of the siphon stands higher, for example, than required for compensation. Then, since an equal excess of mercury occupies the opposite branch of the U, we have:

$$V_1 - V_0 = 2\frac{\pi d^2}{4}y.$$

Hence,

$$\Delta h = y(m-g)(t-t_0),$$

or, for ordinary glass,

$$\Delta h = 0.0000865\,y(t-t_0).$$

Magnifying and recording mechanisms.

In the barograph illustrated, the barometric changes are magnified five times and recorded on a vertical drum adapted to embrace a change of 2 inches of pressure and revolving once in three days, moving at the rate of about a quarter of an inch per hour. A long experience with a variety of scales indicates that records on time and pressure scales of about the above proportions give, on the whole, the most satisfactory and graphic picture of ordinary barometric oscillations. Even the sudden changes that sometimes accompany thunderstorms are very well brought out; but for the most detailed effects of this character a more rapid time scale is necessary. The magnification is sufficiently great to show admirably the small fluctuations of a few thousandths to some hundredths of an inch that sometimes occur for hours at a time.

In the siphon form of barometer the change of level of the mercury in either leg is only half of the whole change, assuming both legs to have the same diameter, and, since we measure effects in the open leg only and desire a fivefold magnification, it follows that an actual tenfold magnification of the

[2] Hough, Prof. G. W., Annals of the Dudley Observatory, Albany, N. Y., 1866, Vol. 1, p. 88.
[3] Goulier, C. M., Comptes rendus, 1877, Vol. 84, p. 1315.

movements of the float are necessary. This is accomplished by a large and small wheel operating on the principle of the wheel and axle, as may be clearly seen in figs. 1 and 3. This construction provides a perfectly balanced system which is itself neutral in all positions and at the same time admits of a wide range of movement, results impossible to secure with lever systems commonly employed in case of this kind.

In order to secure strength of construction and at the same time reduce friction to a minimum the multiplying wheels and axle are mounted on carefully designed and constructed ball-bearings, each cell containing only six balls, each one-sixteenth inch in diameter. The ends of the axle entering the ball cups are cones of 70°.

A conical steel float, with the base somewhat hollowed out so as to conform fairly well to the shape of the surface of mercury, rests lightly upon the top of the column and is suspended from the small drum of the wheel and axle system by means of a narrow platinum ribbon about 0.001 inch thick. The pen-carrier is suspended by a very fine copper wire running in a groove in the rim of the large wheel, the diameter of which is approximately 5 inches, while that of the drum is one-tenth as great. The exact ratio of these wheels is planned to realize a fivefold magnification of pressure changes; due account being taken of any slight differences in the diameters of the open and closed chambers of the barometric column.

To realize a condition of minimum friction great attention is necessary in the design and arrangement of the pen-carrier; first, its weight is the least practicable since the mass of the float must be somewhat in excess of ten times that of the pen-carrier, and any unnecessary weight in these parts introduces avoidable friction on the axle. Second, the pen-carrier is guided and constrained to move, without sensible looseness, in a definite vertical line by sliding along a fine, stretched wire; but the whole arrangement is so poised and balanced that if not disturbed by exterior influences the carrier will rise and fall in exactly the same vertical line, as nearly as may be, even when the wire is removed. This adjustment serves to eliminate any sliding friction experienced by the pen-carrier, not absolutely essential to constraining the pen to the desired vertical line. Finally, the contact pressure of the pen on the record sheet is no greater than essential and results from a small residual gravitational tendency of the carrier to rotate the pen point against the record sheet with a very gentle pressure. The siphon tubes are about 1¼ inches in diameter and the float is only slightly smaller. This gives a moving force capable of overcoming the unavoidable friction in a highly satisfactory manner, and the absence of any complicated mechanisms renders false and interrupted records almost an impossibility.

Time checks on record sheet.

As thus far discribed the barograph is complete and with the aid of the driving clock and drum, which require no further description, gives exceedingly accurate and continuous records. The detailed analysis of barometric records generally requires hourly readings. When record sheets with ruled scales for pressure and time are employed, there is always a difficulty in setting the record so that the ruled hour lines on the sheet indicate the true time. A similar difficulty arises in setting the pen to the correct point on the pressure scale. This, however, is of slight consequence if sheets are properly printed, cut with uniform margins and carefully placed on a cylinder.

To easily secure an equally satisfactory result with the time record the driving clock is provided with a dial and hands in the usual fashion. These moving continuously day after day enable the clock to be regulated to keep correct time, a result very hard to secure when the rating is done on record sheets that are frequently changed. More especially, however, the barograph is equipped with a special time-marking device which automatically operates once each hour at the instant the minute hand of the clock reaches XII, or the zero point of the hour. Nearly all the time lines are omitted from the printed rulings of the record sheet, and the marker operates so as to lift the float a few hundredths of an inch and immediately release it suddenly. This causes the recording pen to oscillate a few times up and down, and to inscribe a short transverse line across the pressure record. These transverse strokes are, in fact, the hour lines for the entire record, and are inscribed with all the accuracy required.

A further advantage results from the action of the time marker. Since the float is slightly raised from the mercury, and subsequently executes several oscillations, there results a general breaking up and renewal of the forces of buoyancy and capillarity which determine the exact position of the float, and at the end of the oscillations any failure of the pen to return exactly to its original position is an index of the magnitude of errors that arise partly from friction and partly from the variations in the capillar and buoyant forces which support the float.

Discontinuities of several thousandths of an inch, due to these causes, are sometimes found and thus render apparent small errors of this kind the existence of which would otherwise be only conjectured.

The time-marker.—The time-marker is shown in fig. 3 and consists of an electromagnet, the circuit of which is closed by a spring contact momentarily operated by the minute hand of the clock as it passes the XII point of the dial.

The armature of the magnet is shaped thus: ┐, as seen in the picture. A long, light, horizontal rod is pivoted at the deprest end of the ┐-formed armature, and is partly lifted by the pull of a spring also carried on the armature. The outer end of the long arm is tipt with a bit of soft rubber, and is loaded with a small counterweight which rests lightly on a small post or stop provided for that purpose.

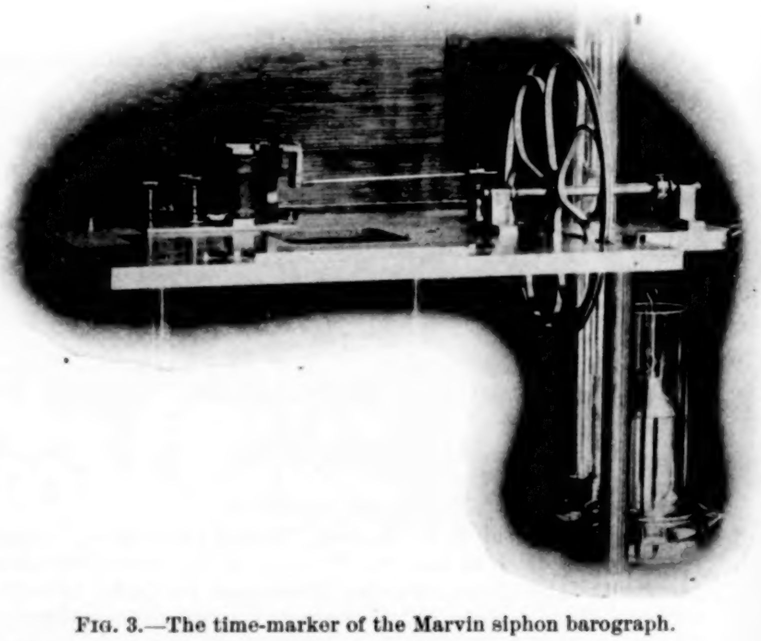

FIG. 3.—The time-marker of the Marvin siphon barograph.

The action of the marker is as follows: When the armature is suddenly pulled down upon the magnet the rubber-tipped rod is thrust forward against the rim of the large wheel. The inertia of the counterweight suffices to overcome for an instant, but only for an instant, the pull of the spring previously mentioned. In this instant, however, the rubber-tipped end

of the rod has engaged the rim of the wheel, and the slower-acting pull of the spring then lifts the rod and thus turns the wheel a small distance (one to two-tenths of an inch). As soon as the armature is released by the breaking of the contact in the clock the wheel and float are released and oscillate freely for a moment, producing the results already fully explained.

The recording drum makes a complete rotation in seventy-four hours, i. e., three days and two hours. Sheets ordinarily are changed at any time between 11 a. m. and noon—preferably shortly after 11 a. m. The new record is therefore fully started before noon, and a check reading of the standard barometer is made as nearly as possible at noon. This furnishes a check observation for determining the starting error of the barograph. Further checks may be obtained subsequently from the regular observations at 8 a. m. and 8 p. m.

A small section of an actual record is reproduced in fig. 4, which shows some of the more marked and periodic oscillations that sometimes occur. The fine details accurately brought out in these records are of themselves an index of the exact manner in which the pen responds to minute changes of level of the mercury.

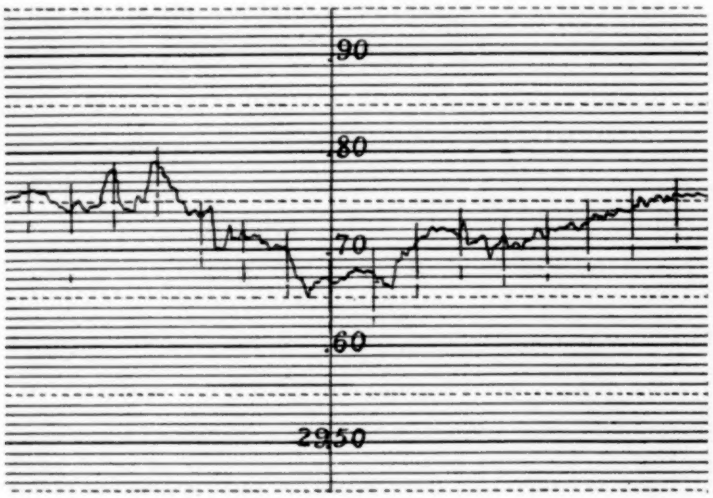

Fig. 4.—Small section of an actual record by the Marvin siphon barograph.

HOW BAROMETER TUBES MAY BE FILLED.

Processes that may be followed in filling barometer tubes for high-grade instruments are so rarely described and so little known, that a short description of some methods frequently employed at the Weather Bureau with highly satisfactory results will doubtless be of interest to a number of readers and serve to accomplish the purposes of this paper more fully.

The object of any filling process is simply to introduce pure mercury and totally exclude all air, moisture, or other foreign matter, especially of a gaseous nature, that may possibly later enter the barometric vacuum and cause errors by the pressure it exerts on the top of the mercurial column.

Cleaning the tube.

In all cases it is of great importance that the inside walls of barometer tubes be perfectly clean. New tubes are thoroly cleaned with whiting or other suitable means while open at both ends, and while still warm and dry the top end is closed and the cistern end tapered and finally fused shut.

Small tubes (one-quarter inch and less) that have become soiled by use, exposure, etc., can not be easily cleaned properly and such are never used a second time in the Weather Bureau work. The methods given in a paragraph below for cleaning larger tubes may, however, be used even with these. The results obtained by the funnel method will be much better if the walls of the tube are strongly heated just before filling and warm mercury introduced while the tube is still warm.

Cleaning large tubes.—Tubes that have contained mercury of which oxidized and impure portions may still adhere more or less closely to the wall, should first be treated with dilute nitric acid (one part in twenty), and then thoroly rinsed with plenty of water. Ammonia or some other alkali may be added if desired, after which the operations described below should be followed.

Introduce several inches of soapy water and whiting with tissue paper pulp. It is often easiest to twist up loosely and put into the tube several small sheets of cheap straw or manilla tissue paper, and add the water and whiting afterwards.

This creamy mass can be strongly shaken about inside the tube, and serves to scour the walls in a very satisfactory manner. It is then removed by copious rinsing with clean water, ending finally with some changes of distilled water. After draining some minutes several applications of strong alcohol in moderate quantities are introduced and drained out and the tube given a final draining for a half hour or so, if convenient, after which it is ready for drying and filling.

Funnel method.

It may seem that the desired result could be obtained by carefully introducing clean mercury thru a long, slender-stemmed funnel reaching quite to the bottom of the barometer (see fig. 5). A suitable funnel may easily be made by drawing down the end of a short piece of rather wide tubing. Such a method is sometimes used and will, indeed, give approximate results, but it will be found upon investigation that while the mercury seems to drive out all the air, yet a good deal will still be found in the vacuum. Originally, this air mixt with water vapor is strongly adherent to the walls of the glass tube by reason of a peculiar property of this character which glass is found to have. When the barometric vacuum is formed, some of the gaseous matter thus attached to the tube is liberated and, by its pressure, depresses the mercurial column several hundredths of an inch, as has been shown by careful experiments.

One very simple and excellent method of driving off nearly all the air and moisture condensed on the glass walls is given in the next paragraph.

The boiling method.

This is a simple method commonly employed with all small tubes, say one-fourth inch diameter, more or less; such, for example, as are required in the several types of barometers that are employed for the ordinary station observations. Much larger tubes are frequently boiled, but these when more or less full of hot mercury are heavy to handle, a strong heat is required, and the danger of serious accidents is considerable.

It is well, at first, to warm more or less the whole tube and the cup of clean filtered mercury from which the supply is drawn should also be gently warmed.

Sufficient mercury to fill the tube three or four inches is introduced by the aid of a funnel such as shown in fig. 5, except that the slender stem need be only two or three inches long. In the absence of such a funnel it is quite as well to employ a small paper cone of the kind commonly used in filtering mercury. The mercury in the tube is then boiled carefully over a good Bunsen burner flame (see fig. 6). For this purpose the tube is held easily in the hands and moved continuously thru the flame and rotated so as to avoid undue local heating of the tube. As the heating proceeds, the air and moisture vapor first form minute silvery-white bubbles, giving the tube a frosted appearance. These enlarge, and after actually boiling the mercury for a while all evidence of formation of bubbles on the wall disappears and further boiling of the mercury takes place with sudden bursts and a sort of violence, accompanied by sharp metallic clicks as the portions of the boiling mercury strike each other or the walls of the tube. When it is apparent the gases on the walls of the tube have

been driven off sufficiently, a fresh quantity, three or four inches, of warm mercury is added, and this portion then heated and boiled. The line of separation between the new and the old mercury is rendered plainly conspicuous by the frosted appearance previously mentioned.

These operations are repeated until the mercury reaches 3 or 4 inches from the tip of the tube, the latter portion being filled by the careful use of the funnel without boiling.

FIG. 5.—The funnel method of filling barometer tubes.

FIG. 6.—The boiling method of filling barometer tubes.

If the walls of the tube are clean and dry this method is easy to employ and gives very high vacua. The presence of dirty spots on the glass and tubes with damp walls cause greater or less trouble and possibly protracted boiling with other complicated effects.

The air pump method.

This method, with numerous modifications, has been employed by the writer in a large number of cases with very satisfactory results. The method requires a good air pump, drying tubes, beakers, burners, stands, etc., such as are generally available in any physical laboratory.

The apparatus is arranged as shown in fig. 7. The exhaustion and funnel tube F*f* will probably require to be made up to suit requirements by some one a little familiar with simple glass-blowing operations. For most purposes this may be attached to the barometer tube by a short piece of soft, pure rubber tubing R. The outside end of the funnel is drawn down into a long capillary extension which is bent several times as shown so as to dip into the cup of mercury, M. Too fine a capillary should be avoided, and it is generally necessary and easy to weaken the capillary, as at *a*, by heating it a little so that later the tube will break off at this point when a torsional strain is put upon it by twisting the bent extremity, *a*, *b*, *c*. The point at *c* is closed by fusion to begin with. A stop-cock may be employed, as at *d*, and in this case the breaking of the tube is not required, but if the stop-cock leaks even a little the result may be defective and the arrangement first described is often best.

Drying and filling the tube.—In order to dry the tube it is alternately exhausted pretty completely and dry air admitted while the walls are more or less continuously heated by playing over the tube with the flame from a Bunsen burner. These operations must be repeated ten or more times and the tube kept hot. Thruout these operations the mercury is excluded and the funnel tube partakes at least partly in the drying influences.

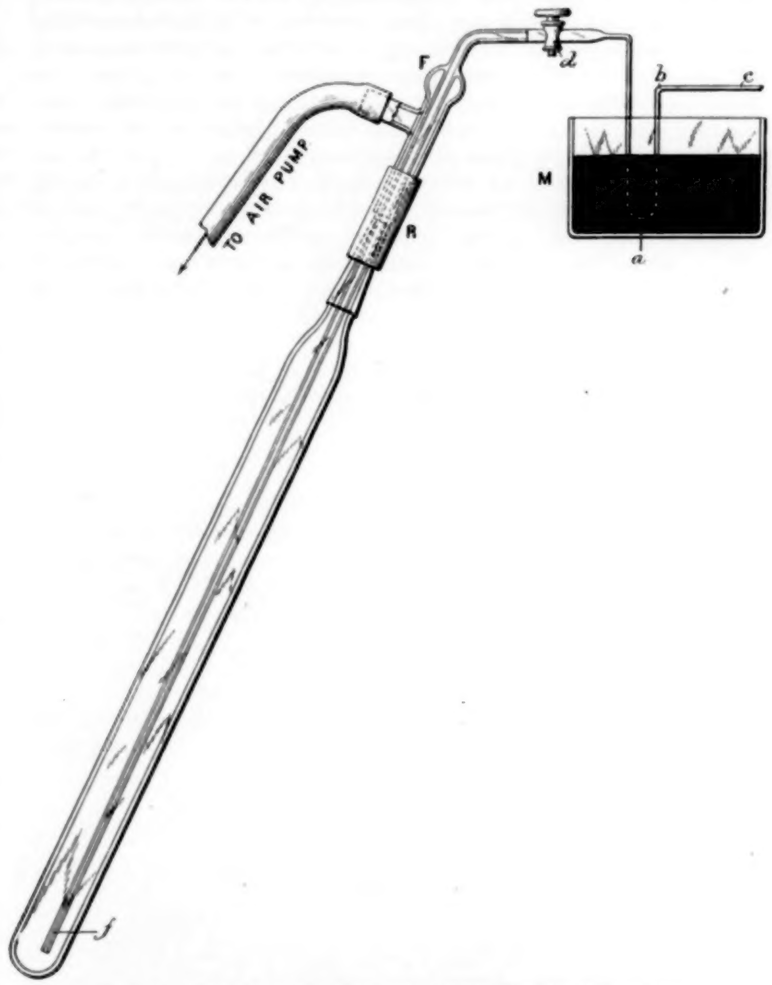

FIG. 7.—The air-pump method of filling barometer tubes.

While the tube is kept quite warm and the vacuum maintained at a high point the capillary is broken at *a* and the mercury in M, which has been heated in the meantime, is permitted to flow. M need not be large enough to contain all the mercury required, but additions may be frequently made and the whole kept quite warm. The filling will take place slowly, depending upon the size of the bore of the inlet tube. The vacuum must be maintained at a high point until the mercury fills the barometer tube when the flow may be stopt by admitting air to the pump. The vessel M must also be removed if there is any tendency for the mercury to flow one way or the other by gravitation.

For the very finest effects the barometer tube can be exhausted by a Sprengel or other high vacua pump, but in this case the rubber tube connections must be replaced by glass and fused joints.

It may be remarked here, that the very high vacua with which we are familiar now-a-days in X-ray and other such tubes, are by no means essential except in the highest grade of *normal* barometers where results depend upon the absolute height of the mercurial column. In the case of instruments in which a correction is found by comparison with a normal, and especially in barographs where the results depend entirely upon differences in the position of the mercurial column, simple methods of filling give entirely satisfactory results. In these cases the pressure due to gases that may be in the vacuum is so nearly constant that no serious error is involved.

Suppose, for example, that the residual air in a barograph tube exerts a pressure of 0.1 inch, which would be inexcusably bad filling. Now, since we set the pen of the barograph to agree, from time to time, with a standard barometer, the only effect the air can have is such as results from changes in temperature or changes in the volume of the vacuum chamber. A 20° change of temperature between settings of the pen is not usual, but in this case would introduce an error of only about 0.003 inch, whence, with reasonably good filling and fairly uniform temperatures the errors from imperfect vacuum are entirely insignificant.

THE WEATHER OF THE MONTH.

By Mr. P. C. DAY, Acting Chief, Climatological Division.

PRESSURE AND WINDS.

The distribution of mean atmospheric pressure for September, 1908, over the United States and Canada, is graphically shown on Chart VI, and the average values and departures from the normal are shown for each station in Tables I and III.

The average sea-level pressure was highest over the upper Ohio Valley and the Middle Atlantic States where the monthly means ranged from 30.10 to 30.15 inches. A similar area with somewhat lower pressure covered the North Pacific coast. A ridge of slightly less average pressure extending eastward and westward across the central portions of the United States connected the above high areas and the pressure diminished northward and southward by moderate gradients.

Pressure averages were slightly below normal over the Canadian Northwest Provinces and at a few points in the extreme Eastern Maritime Provinces; elsewhere over all districts in the United States and Canada the normal was exceeded. Over the Middle Atlantic States it was about .05 inch above, and slightly in excess of that amount over portions of the southern Plains region, and from .05 to .10 inch above over the greater part of the Plâteau and Pacific coast districts.

From August to September, 1908, there was a decided increase in pressure over nearly all districts in the United States and over the Canadian Provinces from the Lake region eastward. Over the Florida Peninsula and along the immediate Gulf coast there was a decrease ranging from .01 inch at Jacksonville, Fla., and New Orleans, La., to .08 inch at Key West, Fla. Over the upper Missouri Valley and extending northward into the Canadian Northwest Territories the pressure for September was slightly less than that for August.

Due to the ridge of high pressure extending across the central portions of the United States southerly winds were dominant over nearly all northern districts from the Atlantic to the Pacific, while over the southern portions, especially east of the Mississippi Valley, they were largely from northerly points.

Over the east Gulf and Atlantic coast States there was a general excess of wind movement, but over nearly all the remaining districts of the United States the average wind velocities were considerably less than the normal rate, the deficiency being most pronounced over the southern portion of the Plains region where the wind movement at points was from 20 to 40 per cent less than the average. The great interior districts were remarkably free from severe atmospheric disturbances, the few storm tracks being confined mostly to the more northern districts or off the Atlantic coast.

TEMPERATURE.

September, 1908, was unusually warm over the greater part of the United States and over the whole of Canada as far north as the field of observations extends.

From New England westward over the Lake region, the Ohio, Mississippi, and Missouri valleys to the Rocky Mountains the average for the month ranged from 3° to 7° above the normal.

Over the Atlantic coast districts from southern New England to Florida, along the Gulf coast, in portions of Texas, and at points on the Pacific coast, the average temperature was below the normal by small amounts.

During the first three weeks the temperatures were above the normal over nearly all districts, except along the Atlantic coast, being especially high during the second and third weeks over the great interior agricultural districts. Cooler weather prevailed during the latter part of the month over the districts from the Great Plains westward, but unseasonably warm weather continued to near the end of the month over the districts from the Mississippi Valley eastward. The mean temperature during the second, third, and fourth weeks over the Lake region, Ohio and upper Mississippi valleys, ranged from 10° to 15° per day above the average. During the third week cool weather set in over the Pacific coast and extending eastward covered the Rocky Mountain districts during the following week and the remaining districts farther east by the end of the month.

Maximum temperatures from 90° to slightly above 100° were recorded at intervals during the month over all districts east of the Rocky Mountains, except from the Appalachian Mountains eastward to the Atlantic, over the lower Lake region and New England. Maximum temperatures above 100° were recorded in the interior valleys of California and southwestern Arizona, and they were above 90° over most of the Plateau region.

Minimum temperatures near the freezing point occurred during the latter part of the month as far south as central Texas and from thence northeasterly over the central Mississippi Valley district to the lower Lake region and portions of New England. Temperatures below 20° were recorded over large portions of the central Rocky Mountain and Plateau districts, and below 10° at exposed points in the mountains of Colorado and Wyoming. The minimum temperatures during the latter part of the month were among the lowest ever recorded for September at many points from the north Pacific coast southeasterly over the Plateau, Rocky Mountain, and Great Plains districts to central Texas.

PRECIPITATION.

Precipitation was unusually heavy along the Gulf coast, southeastern Georgia, and over most of the Florida Peninsula, where some very heavy monthly falls occurred, the amount recorded at Jacksonville, 21.79 inches, being the greatest monthly fall in the history of that station. Amounts from 2 to 6 inches occurred over the districts east of the Appalachian Mountains from Maryland southward, and similar amounts were received from Missouri and eastern Kansas southward over most of Arkansas, Oklahoma, Louisiana, and eastern Texas. Unusually heavy precipitation for the section occurred over the central portions of Utah, where the amounts were several times greater than the average.

The severe drought inaugurated during the latter part of August over the Lake region, Ohio and upper Mississippi valleys and adjoining districts continued into September with increasing severity. No general rains occurred over large portions of the above districts from about the 17th of August

until near the end of September, a period unequaled for length of duration without material rainfall in the history of many points in that region. During this period unusually warm weather prevailed thereby intensifying the drought conditions by excessive evaporation. Many springs, wells, and streams dried up and the water in all streams was extremely low, many important industries were compelled to suspend operations and much inconvenience and financial loss were occasioned. The intense heat and dryness augmented the opportunities for the spread of forest fires, and these latter were unusually destructive over portions of New England, New York, western Pennsylvania, and the northern portions of Michigan and Wisconsin.

General rains over the affected districts near the end of the month relieved the pressing need of surface moisture and partially quenched the forest fires, but the amounts were generally insufficient to materially replenish the sources of the streams, and the water supply at the end of the month was still unusually low in many portions of the districts.

The fact that the soil was generally well saturated with moisture over a large part of the district embraced by the drought and the comparative lateness in the growing season prevented any widespread damage to vegetation from the great lack of moisture.

A more complete history of this drought and some comparisons with others will appear in the MONTHLY WEATHER REVIEW for October, 1908.

Precipitation was above the normal over portions of the South Atlantic States, the Florida Peninsula, portions of Oklahoma, Arkansas, Louisiana, and eastern Texas, southern Minnesota, Utah, southern California, and generally over the Plateau and Rocky Mountain districts. Over the remaining districts there was a general deficiency in precipitation amounting to about 2 inches from New England westward to the Lake region, upper Mississippi and lower Missouri valleys, and southward over the Ohio Valley. There was a deficiency of about 2 inches in the lower Rio Grande Valley and a similar amount over the western portions of Oregon and Washington.

HUMIDITY AND SUNSHINE.

The average relative humidity was below the normal from New England westward to the upper Missouri Valley and southward over the greater part of the Atlantic coast and east Gulf districts, Ohio and lower Missouri valleys. In the lower Lake region and portions of the Ohio Valley the averages were from 10 to 15 per cent below the normal. There was also a deficiency in the relative humidity over the southern Rocky Mountain region and over most of the Pacific coast States. Humidity was above the average along the Gulf coast, over the southern portion of the Plains region, and generally over the Plateau and northern Rocky Mountain districts.

Considerable cloudy, foggy weather prevailed along the Atlantic coast, over the Florida Peninsula, and the southern portions of the Gulf States, and along the north Pacific coast. Over the greater part of the Great Plains, the Missouri, Mississippi, and Ohio valleys the sunshine was excessive, being almost continuous during the greater part of the month. Over the greater part of the Lake region, New England, and portions of the Middle Atlantic States much smoke from forest fires prevailed during the latter half of the month, being so dense at times as to cause considerable inconvenience to navigation on the lakes and waterways.

Auroras were reported from a wide extent of territory during the latter part of the month, those of the 29th and 30th being of extraordinary brilliancy and apparently covering the entire northern portion of the United States and large portions of Canada and Alaska.

WEATHER IN ALASKA.

Over the southern coast districts the temperatures continued above freezing thruout the month, except on the higher elevations. The weather was mostly cloudy and rain was of almost daily occurrence, the amounts for the month ranging generally from about 10 to nearly 25 inches. Over the districts about Cook Inlet and the mouth of the Copper River the minimum temperatures were generally near the freezing point; the weather was cloudy and the rainfall moderate. The first snow of the season occurred about the 16th. In the Upper Yukon district the minimum temperatures were generally below freezing, reaching their lowest points about the 25th, when they were but slightly abovo zero. The weather was mostly cloudy, with light rain at frequent intervals and some snow toward the end of the month.

In Canada.—Director R. F. Stupart says:

The temperature was well above the average in all portions of the Dominion; the most noticeable positive departures were 6° to 8° in the Lake Superior district, 4° to 5° in Saskatchewan and Manitoba, and 3° to 5° in the Peninsula of Ontario, and in the Ottawa and upper St. Lawrence valleys.

During the month a severe drought occurred in nearly all portions of the Dominion, the Province of Manitoba proving the exception to the rule with a rainfall in most localities of from 3 to 19 per cent more than the usual amount. In parts of southern Alberta and more locally in southwestern Saskatchewan the rainfall was nil; elsewhere from coast to coast, except in Manitoba as already stated, the quantity recorded was equivalent to about a third of the average.

Average temperatures and departures from the normal.

Districts.	Number of stations.	Average temperatures for the current month.	Departures for the current month.	Accumulated departures since January 1.	Average departures since January 1.
		°	°	°	°
New England	12	63.0	+ 2.1	+ 6.2	+ 0.7
Middle Atlantic	16	66.8	+ 0.2	+ 1.3	+ 0.1
South Atlantic	10	72.0	— 1.0	+ 7.3	+ 0.8
Florida Peninsula*	8	79.2	— 0.1	+ 7.1	+ 0.8
East Gulf	11	75.2	+ 0.4	+ 9.8	+ 1.1
West Gulf	10	75.5	+ 0.1	+13.2	+ 1.5
Ohio Valley and Tennessee	13	71.2	+ 2.9	+11.7	+ 1.3
Lower Lake	10	66.4	+ 3.5	+ 5.3	+ 0.6
Upper Lake	12	64.5	+ 5.6	+15.9	+ 1.8
North Dakota*	9	60.6	+ 3.6	+20.5	+ 2.3
Upper Mississippi Valley	15	69.3	+ 4.5	+14.2	+ 1.6
Missouri Valley	12	69.8	+ 4.6	+20.3	+ 2.3
Northern Slope	9	59.6	+ 2.2	+ 8.9	+ 1.0
Middle Slope	6	68.8	+ 1.3	+14.8	+ 1.6
Southern Slope*	7	71.9	— 1.1	+ 6.9	+ 0.8
Southern Plateau*	12	69.8	— 0.8	— 2.5	— 0.3
Middle Plateau*	10	59.5	— 0.8	— 4.2	— 0.5
Northern Plateau*	12	59.5	+ 1.2	+ 5.8	+ 0.6
North Pacific	7	56.0	— 0.9	— 1.8	— 0.2
Middle Pacific	8	64.9	+ 0.5	— 0.1	0.0
South Pacific	4	68.5	+ 1.2	+ 4.8	+ 0.5

* Regular Weather Bureau and selected cooperative stations.

Average precipitation and departures from the normal.

Districts.	Number of stations.	Average.		Departure.	
		Current month.	Percentage of normal.	Current month.	Accumulated since Jan. 1.
		Inches.		*Inches.*	*Inches.*
New England	12	1.05	33	—2.10	—4.70
Middle Atlantic	16	2.30	70	—1.00	—1.10
South Atlantic	10	4.78	102	+0.10	+1.60
Florida Peninsula*	8	10.55	136	+2.80	—1.70
East Gulf	11	3.62	93	—0.30	—0.80
West Gulf	10	4.62	135	+1.20	+2.80
Ohio Valley and Tennessee	13	1.18	42	—1.60	—2.80
Lower Lake	10	1.03	36	—1.80	—1.10
Upper Lake	12	2.06	63	—1.20	—0.90
North Dakota*	9	1.04	72	—0.40	+0.30
Upper Mississippi Valley	15	1.83	55	—1.50	+0.50
Missouri Valley	12	0.91	33	—1.80	+1.30
Northern Slope	9	1.20	109	+0.10	+2.60
Middle Slope	6	1.90	95	—0.10	+4.60
Southern Slope*	7	2.69	96	—0.10	+4.60
Southern Plateau*	12	0.69	70	—0.30	+0.50
Middle Plateau*	10	1.30	168	+0.50	+0.90
Northern Plateau*	12	0.93	100	0.00	—1.10
North Pacific	7	0.69	28	—1.80	—4.40
Middle Pacific	8	0.06	11	—0.50	—4.40
South Pacific	4	0.60	300	+0.40	—0.72

* Regular Weather Bureau and selected cooperative stations.

Average cloudiness and departures from the normal.

Districts.	Average.	Departure from the normal.	Districts.	Average.	Departure from the normal.
New England	4.9	− 0.1	Missouri Valley	3.4	− 0.6
Middle Atlantic	4.8	0.0	Northern Slope	4.0	0.0
South Atlantic	4.7	− 0.1	Middle Slope	3.1	− 0.1
Florida Peninsula	5.6	+ 0.1	Southern Slope	3.3	+ 0.3
East Gulf	5.3	+ 0.9	Southern Plateau	2.3	0.0
West Gulf	4.9	+ 0.6	Middle Plateau	3.5	+ 1.0
Ohio Valley and Tennessee	3.2	− 1.2	Northern Plateau	3.8	− 0.3
Lower Lake	2.9	− 1.9	North Pacific	4.9	0.0
Upper Lake	4.4	− 0.7	Middle Pacific	4.1	+ 1.3
North Dakota	4.0	− 0.3	South Pacific	3.2	+ 0.7
Upper Mississippi Valley	3.3	− 0.9			

Average relative humidity and departures from the normal.

Districts.	Average.	Departure from the normal.	Districts.	Average.	Departure from the normal.
New England	78	− 3	Missouri Valley	63	− 3
Middle Atlantic	76	− 1	Northern Slope	58	+ 3
South Atlantic	80	0	Middle Slope	63	+ 5
Florida Peninsula	83	+ 1	Southern Slope	67	+ 4
East Gulf	76	0	Southern Plateau	44	+ 2
West Gulf	77	+ 3	Middle Plateau	47	+ 9
Ohio Valley and Tennessee	66	− 6	Northern Plateau	51	− 1
Lower Lake	66	− 7	North Pacific	76	− 2
Upper Lake	74	− 3	Middle Pacific	59	− 4
North Dakota	65	− 1	South Pacific	66	0
Upper Mississippi Valley	70	− 2			

Maximum wind velocities.

Stations.	Date.	Velocity.	Direction.	Stations.	Date.	Velocity.	Direction.
Alpena, Mich	30	51	s.	Mount Weather, Va	28	57	nw.
Canton, N. Y	28	52	sw.	Oklahoma, Okla	22	56	n.
Galveston, Tex	17	62	ne.	Point Reyes Light, Cal.	6	50	nw.
Jacksonville, Fla	6	57	w.	Do	7	59	nw.
Minneapolis, Minn	22	50	w.	Do	14	53	nw.
Modena, Utah	6	56	sw.	Do	15	50	nw.
Do	16	52	sw.	Do	16	63	nw.
Mount Tamalpais, Cal	6	60	nw.	Do	17	52	nw.
Do	7	58	nw.	St. Paul, Minn	22	52	nw.
Do	14	62	nw.				

CLIMATOLOGICAL SUMMARY.

By Mr. P. C. DAY, Acting Chief, Climatological Division.

TEMPERATURE AND PRECIPITATION BY SECTIONS, SEPTEMBER, 1908.

In the following table are given, for the various sections of the Climatological Service of the Weather Bureau, the average temperature and rainfall, the stations reporting the highest and lowest temperatures with dates of occurrence, the stations reporting greatest and least monthly precipitation, and other data, as indicated by the several headings.

The mean temperatures for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperature and precipitation are based only on records from stations that have ten or more years of observation. Of course the number of such records is smaller than the total number of stations.

Section.	Temperature—In degrees Fahrenheit.								Precipitation—In inches and hundredths.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
Alabama	74.2	− 0.3	Newbern	101	13	Valley Head	33	28	2.42	− 0.54	Daphne	8.83	Cordova	T.
Arizona	74.1	− 1.0	Fort Mohave	117	6	St. Michaels Williams	22 22	27 27	0.85	− 0.21	Paradise	3.37	Pinto	0.05
Arkansas	73.4	0.0	4 stations	101	3 d't's	Corning	29	28	4.00	+ 0.98	Prescott	9.65	Helena No. 1	0.84
California	68.1	+ 0.4	Mammoth Tank	115	3,4	Alturas	15	25	0.49	+ 0.01	Sierra Madre	3.67	20 stations	0.00
Colorado	58.3	+ 0.6	Los Animas Holly	102 102	5,6 6	Westcliff	5	27	0.78	− 0.47	Breckenridge	3.35	Buena Vista	0.00
Florida	78.5	− 0.7	Orange City	98	5	Molino	46	29	9.45	+ 2.32	Jacksonville	21.79	Newport	0.51
Georgia	73.2	− 1.4	Fitzgerald	101	3	Dahlonega Gore	38 38	29 29	3.11	− 0.51	Brunswick	13.34	Eatonton	0.83
Hawaii†	73.7	......	Kihei, Maui	94	28	Humuula, Hawaii	36	22	5.83	......	Honomanu Valley	27.69	2 stations	0.00
Idaho	58.0	+ 1.1	Garnet	102	6	Camas	8	27	1.16	+ 0.11	Big Creek	3.60	Stone	0.11
Illinois	70.3	+ 3.5	Antioch Benton	100 100	11 13	Lanark	26	29	1.31	− 2.10	Martinton	2.60	Fairfield Ottawa	0.35 0.35
Indiana	70.2	+ 3.4	Rome Zelma	101 101	11 11	Cambridge City	30	30	0.97	− 1.79	Hammond	3.90	Richmond	0.41
Iowa	67.9	+ 4.2	Ridgeway	98	11	Washta	20	29	1.20	− 2.21	Grand Meadow	3.46	Jefferson	0.25
Kansas	70.3	+ 1.1	Ashland	105	5	Goodland St. Francis	24 24	27 27	1.71	− 1.17	Sedan	4.94	St. Francis	0.03
Kentucky	71.6	+ 1.4	Bardstown	101	13	Farmers	30	30	1.03	− 1.69	Edmonton	4.43	Bardstown	0.24
Louisiana	76.8	− 0.6	Minden	100	15	Robeline	39	30	6.90	+ 3.29	Cameron	24.28	Newellton	1.55
Maryland and Delaware	66.0	− 1.4	Westernport, Md	94	12	Deer Park, Md	24	30	2.40	− 0.89	College Park, Md	5.14	Oakland, Md	0.48
Michigan	65.2	+ 4.9	3 stations	96	3 d't's	Roscommon	23	3	1.42	− 1.75	Humboldt	4.72	Ann Arbor	0.27
Minnesota	64.2	+ 5.9	Lynd No. 1	99	12	Osakis	21	29	2.41	− 0.55	Lynd No. 2	6.33	Angus	0.17
Mississippi	75.6	+ 0.1	Aberdeen	101	14	Duck Hill	36	30	2.65	− 0.73	McNeill	9.41	Agricultural College	T.
Missouri	71.6	+ 2.2	Warsaw	99	16	Linneus Unionville	28 28	29 29	1.80	− 1.85	Lebanon	4.42	Parkville	T.
Montana	57.0	+ 2.5	Fallon Miles City	106 106	7 7	Raymond	6	25	1.63	+ 0.58	Browning	3.66	2 stations	0.48
Nebraska	68.2	+ 3.8	Kirkwood	107	8	Fort Robinson	9	27	0.76	− 1.47	Anoka	2.79	2 stations	0.00
Nevada	59.8	− 0.3	Logan	108	5	Elko Wells	6 6	26 25	0.82	+ 0.43	Jean	2.71	Wells	0.00
New England*	62.5	+ 2.4	Lewiston, Me	95	10	Van Buren, Me	23	21	1.09	− 2.77	Nantucket, Mass	2.98	Patten, Me	0.30
New Jersey	65.7	− 0.6	Layton Brown's Mills	90 90	11 25	Charlotteburg	29	30	2.09	− 1.91	Atlantic City	4.13	Long Branch	0.95
New Mexico	64.1	− 1.3	Cliff Tularosa	98 98	19 9	Winsors	12	27	0.56	− 1.19	Mimbres	1.83	4 stations	0.00
New York	63.8	+ 2.9	Addison	96	25	Bensons Mines Indian Lake	23 23	15 16	1.40	− 1.92	Liberty	3.40	Lyndonville	0.42
North Carolina	68.9	− 1.9	Kinston	95	7	Banners Elk	29	30	2.69	− 1.15	Vade Mecum	6.43	Kinston	0.47
North Dakota	60.7	+ 4.7	3 stations	104	7	Berthold Agency	16	28	1.11	− 0.38	Donnybrook	2.76	Dunseith	0.19
Ohio	68.0	+ 2.4	Jacksonburg Marion	100 100	3d't's 24	North Lewisburg	23	30	0.58	− 2.15	Clarington	2.25	New Waterford	0.04
Oklahoma	72.7	− 1.0	Buffalo Cloud Chief	106 106	5 6	3 stations	30	3 d't's	4.45	+ 1.92	Jefferson	12.19	Kenton	0.15
Oregon	59.2	+ 0.4	4 stations	100	4,5	Christmas Lake	9	25	0.46	− 1.32	Granite	1.71	3 stations	T.
Pennsylvania	65.6	+ 1.7	Irwin	99	1	Saegerstown	26	30	1.60	− 1.86	New Germantown	4.06	Johnstown	0.51
Porto Rico	78.7	......	Arecibo	101	13	Las Marias	54	27	8.96	......	Central Ingenio	15.15	Culebro	3.93
South Carolina	72.4	− 1.8	Walterboro	94	2,7	Liberty	40	29	2.79	− 1.14	Camden No. 2	6.98	Ferguson	0.62
South Dakota	67.0	+ 6.5	Ottumwa	110	7	4 stations	21	3 d't's	1.32	− 0.31	Brookings	3.89	Rosebud	0.01
Tennessee	71.0	+ 0.4	Dover	101	13,14	Rugby	28	29,30	1.93	− 1.11	Hall's Hill	10.11	Bluff City	0.26
Texas	75.4	− 0.8	Fairland Bowie	107 107	5 6	3 stations	31	27,28	3.28	+ 0.21	Galveston	14.64	Marfa	0.00
Utah	59.3	− 1.1	Hite Springdale	102 102	5,6 6	Park City	8	26	1.87	+ 1.02	Silver Lake	4.22	Lucin	0.05
Virginia	66.1	− 2.1	Petersburg Lincoln	93 93	13 11	Burkes Garden	25	30	2.64	− 0.85	Quantico	5.05	Max Meadows	1.26
Washington	59.2	+ 0.1	Zindel	102	12,21	Northport	17	24	0.38	− 1.74	Clearwater	3.19	4 stations	0.00
West Virginia	65.9	− 0.6	Moorfield Valley Fork	99 99	12 23	Bayard	24	30	0.95	− 1.71	Princeton	2.54	Green Sulphur Sp'gs	0.26
Wisconsin	65.5	− 5.2	Richland Center	104	10	Solon Springs	24	30	2.24	− 1.33	Viroqua	4.47	Port Washington	0.55
Wyoming	55.3	+ 0.5	Fort Laramie	101	7	Kirwin	1	27	0.76	− 0.22	Evanston	2.47	Lusk	0.00

* Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut. † Report for August.

DESCRIPTION OF TABLES AND CHARTS.

By Mr. P. C. DAY, Acting Chief, Climatological Division.

For description of tables and charts see page 8 of REVIEW for January, 1908.

TABLE I.—*Climatological data for U. S. Weather Bureau stations, September, 1908.*

Stations.	Elevation of instruments: Barometer above sea level, feet.	Thermometers above ground.	Anemometer above ground.	Pressure, in inches: Actual, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hrs.	Departure from normal.	Temperature of the air, in degrees Fahrenheit: Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity, per cent.	Precipitation, in inches: Total.	Departure from normal.	Days with .01, or more.	Wind: Total movement, miles.	Prevailing direction.	Maximum velocity: Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness during daylight, tenths.	Total snowfall.
New England.							63.0	+ 2.1										78	1.05	− 2.1										4.9	
Eastport	76	69	85	29.97	30.05	+ .02	58.6	+ 3.4	85	11	67	41	20	50	31	52	48	75	1.60	− 1.4	5	6,443	s.	32	s.	29	9	14	7	5.1	
Greenville	1,070	6	....	....	....	....	58.0	....	84	10	72	25	20	44	43	....	....	....	1.90	....	4	....	nw.	....	....	....	....	....	....	....	
Portland, Me.	103	81	117	29.96	30.08	+ .03	62.6	+ 3.0	87	11	71	42	16	54	31	56	52	74	0.69	− 2.5	4	6,343	s.	34	se.	29	21	4	5	3.4	
Concord	288	70	79	29.97	30.10	+ .04	62.0	+ 2.9	88	24	76	33	20	48	42	....	....	....	0.45	− 2.8	4	2,832	se.	20	n.	14	20	8	2	2.8	
Burlington	404	12	47	29.67	30.10	+ .04	63.0	+ 2.1	88	1	75	34	20	51	40	....	....	....	1.15	− 2.2	6	7,546	s.	40	se.	28	6	10	12	6.0	
Northfield	876	16	70	29.17	30.12	+ .06	59.4	+ 4.8	86	27	75	27	20	43	44	53	51	86	0.35	− 2.4	2	5,100	s.	30	se.	28	5	9	16	6.2	
Boston	125	115	188	29.96	30.10	+ .03	65.8	+ 3.1	88	11	74	47	30	58	26	58	54	69	0.68	− 2.5	3	6,696	sw.	30	s.	29	13	8	9	5.3	
Nantucket	12	14	90	30.07	30.08	.00	63.2	+ 0.4	76	28	69	47	20	58	20	59	57	85	2.98	+ 0.2	3	10,011	sw.	48	n.	17	12	7	11	5.7	
Block Island	26	11	46	30.07	30.10	+ .02	63.6	− 0.5	77	19	69	52	30	59	17	60	57	83	0.77	− 2.2	3	8,829	sw.	40	ne.	16	10	6	14	5.7	
Narragansett	....	9	....	....	....	....	62.6	− 0.2	80	17	71	44	4	54	27	....	....	....	1.08	....	3	....	sw.	....	....	....	14	7	9	....	
Providence	160	57	67	29.94	30.11	+ .04	63.8	+ 0.6	88	10	73	44	30	54	32	58	54	78	0.88	− 2.3	4	3,724	sw.	20	s.	29	13	11	6	4.7	
Hartford	159	122	140	29.93	30.10	+ .03	65.4	+ 3.7	88	10	76	40	30	55	35	58	55	77	1.12	− 2.4	3	4,345	s.	32	s.	28	8	15	7	5.3	
New Haven	106	116	155	29.99	30.10	+ .03	65.6	+ 1.7	83	11	74	44	16	57	29	59	54	73	0.88	− 2.9	4	3,259	n.	36	s.	29	13	13	4	4.0	
Mid. Atlantic States.							66.8	+ 0.2										76	2.30	− 1.0										4.8	
Albany	97	102	115	30.00	30.10	+ .03	65.9	+ 3.6	87	1	77	40	30	55	35	88	53	70	0.64	− 2.5	3	4,733	s.	38	se.	28	9	15	6	5.3	
Binghamton	871	78	90	29.20	30.13	+ .05	63.4	+ 3.4	89	23	77	33	30	49	41	....	....	....	1.41	− 1.4	4	3,224	ne.	26	nw.	6	11	7	12	5.4	
New York	314	108	350	29.77	30.10	+ .02	67.8	+ 1.3	83	19	74	53	30	61	20	60	56	72	1.60	− 2.0	3	6,430	ne.	31	w.	29	10	11	9	5.3	
Harrisburg	374	94	104	29.72	30.12	+ .04	67.0	+ 2.1	87	12	77	42	30	57	32	59	54	72	1.50	− 1.4	3	3,747	e.	38	sw.	28	15	10	5	3.9	
Philadelphia	117	116	184	30.00	30.12	+ .04	68.1	+ 0.7	85	19	76	50	30	60	24	60	56	70	1.79	− 1.6	3	5,825	nw.	30	se.	28	12	10	8	4.9	
Scranton	805	111	119	29.26	30.11	+ .04	65.8	+ 3.6	91	23	78	38	30	54	36	57	52	69	2.03	− 0.8	2	3,917	ne.	29	w.	28	9	11	10	5.6	
Atlantic City	52	37	48	30.06	30.11	+ .04	64.4	− 1.2	87	12	72	49	30	60	24	61	58	78	4.13	+ 1.1	5	4,998	e.	28	s.	28	8	9	13	6.0	
Cape May	17	48	52	....	....	....	66.8	− 2.2	84	12	72	46	30	62	20	....	....	....	2.54	− 0.5	6	....	s.	31	s.	28	9	10	11	5.8	
Baltimore	123	100	113	29.98	30.11	+ .03	68.4	− 0.2	86	12	77	47	30	60	27	62	58	75	2.59	− 1.3	4	4,184	ne.	26	s.	28	13	6	11	5.2	
Washington	112	59	76	29.99	30.11	+ .03	66.6	− 1.5	86	12	77	41	30	56	33	60	58	83	4.65	+ 1.1	4	3,481	n.	31	nw.	28	15	8	7	4.3	
Cape Henry	18	9	58	....	....	....	70.0	− 1.8	64	2	75	57	30	64	23	....	....	....	2.42	0.0	5	9,503	ne.	40	ne.	15	11	12	7	....	
Lynchburg	681	83	88	29.39	30.14	+ .06	66.6	− 1.8	86	19	78	42	30	55	37	60	58	84	2.22	− 1.4	4	1,781	ne.	19	nw.	28	15	10	6	4.8	
Mount Weather	1,725	10	54	28.31	30.10	+ .03	64.4	+ 2.0	82	23	72	40	29	57	25	58	54	75	2.27	− 0.6	7	7,210	se.	57	nw.	28	17	6	7	4.0	
Norfolk	91	102	111	30.01	30.11	+ .04	69.6	− 2.1	85	28	76	54	17	63	24	64	61	78	2.28	− 1.8	6	5,829	ne.	33	ne.	15	12	10	8	4.6	
Richmond	144	145	153	29.97	30.12	+ .05	68.4	− 2.4	88	19	78	50	30	59	33	....	....	....	2.74	− 0.7	6	4,076	n.	28	s.	28	13	7	10	4.7	
Wytheville	2,293	40	47	27.78	30.13	+ .06	63.2	− 0.4	85	12	76	34	30	50	38	57	56	92	2.08	− 1.2	4	2,089	se.	24	w.	28	21	6	3	2.8	
S. Atlantic States.							72.0	− 1.0										80	4.78	+ 0.1										4.7	
Asheville	2,255	53	75	27.79	30.11	+ .04	64.6	+ 0.6	86	13	76	36	30	53	34	58	55	80	2.32	− 0.7	3	3,863	se.	27	n.	28	19	9	2	3.0	
Charlotte	773	68	76	29.28	30.10	+ .03	69.6	− 1.1	86	2	79	46	29	60	27	62	58	72	1.50	− 1.7	3	4,090	ne.	20	ne.	16	16	11	3	3.8	
Hatteras	11	12	47	30.05	30.06	.00	72.8	− 1.9	84	7	77	61	17	68	13	69	68	89	3.37	− 2.0	8	10,564	ne.	45	w.	1	15	10	5	4.1	
Manteo	....	....	....	....	....	....	71.2	− 0.6	84	2	77	55	17	65	....	....	....	....	3.67	− 1.7	7	....	ne.	....	....	....	22	5	3	....	
Raleigh	376	71	79	29.70	30.09	+ .02	69.2	− 1.4	86	20	78	47	30	60	27	63	59	77	3.70	+ 0.4	4	5,020	ne.	25	sw.	28	16	8	6	4.3	
Wilmington	78	81	91	29.99	30.07	+ .02	72.0	− 1.1	88	2	80	55	30	64	26	66	64	82	1.45	− 3.8	4	5,472	ne.	25	ne.	15	11	14	5	4.9	
Charleston	48	14	92	29.99	30.04	.00	75.4	− 0.8	89	6	81	59	16	69	21	70	68	82	1.06	− 4.4	5	8,162	e.	34	e.	26	10	12	8	4.9	
Columbia, S. C.	351	41	57	29.70	30.07	+ .02	72.0	− 1.7	91	2	82	50	17	63	29	64	60	74	2.21	− 1.2	6	4,648	ne.	25	sw.	28	11	11	8	4.6	
Augusta	180	89	97	29.87	30.06	+ .01	73.5	− 0.9	91	2	84	49	29	63	28	66	62	74	2.44	− 1.3	5	4,435	ne.	23	ne.	15	13	8	9	4.5	
Savannah	65	81	89	29.96	30.04	+ .01	75.4	0.0	91	7	83	58	30	68	20	69	68	85	9.05	+ 3.5	12	4,858	ne.	21	se.	27	9	8	13	6.0	
Jacksonville	43	101	129	29.96	30.01	+ .01	76.3	− 1.0	90	3	82	64	17	70	19	72	71	90	21.79	+ 13.8	15	6,519	ne.	57	w.	6	5	12	13	6.7	
Florida Peninsula.							80.7	+ 0.2										83	5.48	− 2.2										5.6	
Jupiter	28	10	48	29.92	29.95	− .01	80.2	− 0.4	89	26	86	71	23	74	15	75	74	83	5.72	− 3.8	24	6,924	e.	35	se.	20	2	26	2	5.3	
Key West	22	10	53	29.90	29.92	− .02	82.3	− 0.2	90	7	88	70	22	76	16	76	74	79	7.14	+ 0.4	19	5,088	e.	32	nw.	24	4	20	6	5.7	
Sand Key	25	41	71	29.89	29.92	− .02	81.2	....	90	26	85	70	7	77	15	....	....	....	3.33	− 3.5	16	8,134	e.	34	ne.	12	3	25	2	5.5	
Tampa	35	79	96	29.94	29.97	.00	79.6	+ 1.3	91	15	87	70	13	72	20	73	72	86	5.73	− 1.7	16	5,019	ne.	26	e.	24	5	17	8	5.9	
East Gulf States.							75.2	+ 0.4										76	3.62	− 0.3										5.3	
Atlanta	1,174	190	216	28.85	30.07	+ .02	71.0	− 1.1	90	13	80	45	29	62	24	63	59	71	2.46	− 1.1	5	7,074	ne.	31	nw.	28	17	6	7	4.5	
Macon	370	78	87	29.66	30.06	+ .03	73.2	+ 0.3	91	2	83	49	30	64	29	....	....	....	1.65	− 1.8	5	4,535	ne.	24	s	4	13	5	12	4.9	
Thomasville	273	8	58	29.72	30.01	.00	76.1	− 0.7	95	3	86	53	29	66	31	69	68	85	4.24	0.0	14	3,696	ne.	22	e.	24	9	6	15	6.0	
Pensacola	56	79	96	29.94	30.00	+ .01	76.8	− 1.1	92	13	83	53	29	71	23	....	....	....	4.83	− 0.4	10	6,890	ne.	28	ne.	29	8	10	12	5.8	
Anniston	741	9	58	29.30	30.09	+ .06	72.6	+ 1.3	94	13	84	38	29	62	37	....	....	....	3.82	+ 0.3	5	4,167	e.	24	sw.	5	13	9	8	4.8	
Birmingham	700	11	48	29.31	30.06	+ .03	75.6	+ 1.6	97	13	86	43	29	65	35	65	60	68	0.75	− 2.8	4	4,558	e.	24	nw.	28	7	14	9	5.4	
Mobile	57	98	106	29.94	30.00	.00	77.5	+ 1.0	96	14	85	52	29	70	24	70	67	78	7.32	+ 2.3	12	4,245	ne.	28	e.	8	7	14	9	5.8	
Montgomery	223	100	112	29.79	30.04	+ .02	75.5	+ 0.3	96	13	85	48	29	66	31	66	62	70	1.34	− 1.5	8	4,492	e.	34	ne.	7	12	11	7	4.9	
Meridian	375	84	93	29.63	30.02	.00	74.3	+ 1.6	94	14	85	43	30	64	34	66	62	74	1.76	− 1.7	6	3,509	e.	20	nw.	28	16	7	7	4.5	
Vicksburg	247	62	74	29.74	30.02	.00	76.4	+ 1.6	95	15	85	49	30	67	29	68	65	78	0.97	− 2.4	9	3,958	e.	25	nw.	27	10	13	7	4.7	
New Orleans	51	88	121	29.92	29.97	− .01	77.9	− 0.1	92	14	84	56	29	72	19	72	70	83	10.70	+ 5.9	18	5,431	e.	24	se.	5	4	10	16	6.8	
West Gulf States.							75.5	+ 0.1										77	4.62	+ 1.2										4.9	
Shreveport	249	77	84	29.75	30.01	+ .01	76.6	+ 0.3	95	6	85	44	28	67	28	68	65	78	5.01	+ 1.8	8	3,710	e.	22	nw.	27	11	12	7	4.8	
Bentonville	1,303	11	44	28.70	30.05	+ .03	70.1	+ 1.2	92	6	81	34	28	59	36	....	....	....	3.61	+ 0.1	11	2,922	e.	22	sw.	22	10	5	15	5.8	
Fort Smith	457	79	94	29.55	30.02	+ .01	73.2	+ 0.5	95	6	83	41	28	64	31	66	63	79	3.17	0.0	10	4,603	e.	28	s.	22	8	15	7	5.1	
Little Rock	357	139	147	29.67	30.04	+ .01	74.5	+ 1.4	95	6	84	44	28	66	31	66	62	72	3.27	0.0	7	4,568	ne.	26	nw.	27	12	6	12	5.1	
Brownsville	57	4	....	....	....	....	79.8	....	96	27	89	58	29	71	....	....	....	....	5.01	....	14	....	e.	....	....	....	....	....	....	....	
Corpus Christi	20	48	53	29.94	29.96	+ .01	78.4	− 0.6	92	6	85	53	28	72	26	72	69	80	2.44	− 1.6	10	5,475	se.	31	n.	27	15	5	10	4.7	
Fort Worth	670	106	114	29.31	30.02	+ .03	76.0	− 0.7	99	6	86	40	28	66	34	....	....	....	3.52	+ 0.6	7	4,667	se.	32	n.	23	10	17	3	4.4	
Galveston	54	106	112	29.92	29.98	.00	78.0	− 1.4	90	5	83	54	28	73	25	73	71	80	14.64	+ 9.2	12	6,820	n.	62	ne.	17	11	12	7	5.0	
Palestine	510	73	79	29.46	29.98	− .01	75.5	+ 0.8	96	6	85	43	28	66	29	68	65	79	2.32	− 0.9	7	2,447	ne.	9	n.	10	9	10	11	5.6	
San Antonio	701	80	91	29.24	29.96	.00	77.2	+ 0.1	102	6	88	47	30	66	35	67	63	74	3.92	+ 1.0	7	4,051	se.	40	ne.	23	16	9	5	4.1	
Taylor	583	55	63	29.38	29.99	+ .02	76.0	− 0.9	100	6	86	45	28	66	34	....	....	....	4.30	+ 1.3	12	4,371	n.	25	n.	27	13	9	8	4.4	
Ohio Val. and Tenn.							71.2	+ 2.9										66	1.18	− 1.6										3.2	
Chattanooga	762	106	112	29.30	30.10	+ .04	71.3	+ 0.1	90	13	82	43	30	61	33	64	61	77	3.72	+ 0.5	7	2,854	n.	24	nw.	28	14	11	5	4.2	
Knoxville	1,004	93	100	29.04	30.09	+ .03	70.0	+ 0.6	90	13	81	40	29	59	31	62	59	75	1.78	− 1.0	2	2,406	ne.	23	nw.	6	15	8	7	3.8	
Memphis	399	76	97	29.64	30.06	+ .03	75.0	+ 2.2	95	14	84	44	28	66	31	66	62	71	1.49	− 1.6	4	4,482	e.	36	nw.	27	16	7	7	4.0	
Nashville	546	79	91	29.51	30.09	+ .03	73.0	+ 1.5	95	13	84	41	30	62	38	64	60	73	1.89	− 1.8	5	2,972	se.	25	w.	6	18	8	4	3.4	
Lexington	989	75	102	29.05	30.10	+ .03	71.8	+ 3.9	92	12	84	40	29	60	33	....	....	....	0.38	− 2.0	1	5,462	se.	28	w.	28	24	4	2	1.8	
Louisville	525	111	132	29.51	30.09	+ .03	74.9	+ 5.0	95	12	88	40	30	62	37	61	55	58	0.59	− 2.0	3	3,931	se.	30	w.	28	16	13	1	2.9	
Evansville	431	72	82	29.61	30.07	+ .01	73.8	+ 4.1	93	12	85	42	29	62	37	....	....	....	1.23	− 1.4	2	3,838	s.	24	sw.	30	15	15	0	3.0	
Indianapolis	822	154	164	29.20	30.08	+ .02	71.6	+ 4.9	92	11	84	39	29	60	31	59	51	54	1.14	− 1.9	4	5,156	se.	33	sw.	30	18	10	2	3.0	
Cincinnati	628	152	160	29.42	30.09	+ .02	72.9	+ 3.9	94	12	86	39	30	60	37	59	51	53	0.26	− 2.0	1	3,404	se.	25	w.	28	21	6	3	2.3	
Columbus	824	173	224	29.23	30.10	+ .03	70.4	+ 4.5	93	12	83	37	30	57	37	57	49	55	0.42	− 2.1	2	6,261	se.	38	w.	28	20	7	3	2.5	
Pittsburg	842	336	352	29.21	30.10	+ .02	68.6	+ 2.5	91	12	81	40	30	56	38	58	52	62	0.71	− 1.8	3	4,582	ne.	42	w.	28	22	5	3	2.4	
Parkersburg	638	77	84	29.46	30.11	+ .03	69.0	+ 2.9	93	23	84	34	30	54	43	58	53	68	0.86	− 1.9	3	2,532	s.	33	nw.	6	17	11	2	3.8	
Elkins	1,940	41	50	28.12	30.16	+ .08	63.3	+ 1.4	92	23	80	31	30	46	46	54	52	84	0.88	− 2.0	5	1,523	w.	19	w.	28	17	9	4	3.9	
Lower Lake Region.							66.4	+ 3.5										66	1.03	− 1.8										2.9	
Buffalo	767	178	206	29.26	30.08	+ .02	66.2	+ 3.3	85	26	74	40	29	58	29	58	54	68	1.06	− 2.1	7	8,231	sw.	46	w.	28	16	8	6	3.9	
Canton	448	10	71	29.62	30.09	......	62.4	+ 3.1	87	1	75	35	16	50	35	....	....	....	1.83	− 1.0	4	6,755	sw.	52	sw.	28	23	7	0	1.8	
Oswego	335	76	91	29.71	30.08	+ .02	64.2	+ 1.5	86	1	74	41	30	55	32	57	54	74	1.55	− 1.3	3	6,171	s.	29	se.	28	18	10	2	2.9	
Rochester	523	81	102	29.54	30.10	+ .04	66.0	+ 4.1	89	10	77	41	30	55	32	57	52	68	1.73	− 0.6	5	4,655	sw.	32	w.	28	20	6	4	2.9	
Syracuse	597	97	113	29.47	30.11	+ .04	65.4	+ 3.8	88	25	76	39	30	55	33	....	....	....	0.82	− 2.0	2	6,708	s.	36	se.	28	9	11	10	5.4	
Erie	713	92	102	29.32	30.09	+ .03	66.7	+ 2.8	88	1	75	38	30	58	33	57	51	62	1.15	− 2.3	6	6,794	s.	31	w.	28	19	8	3	3.2	
Cleveland	762	190	201	29.28	30.10	+ .04	66.8	+ 2.5	89	26	76	36	30	57	34	57	52	62	0.48	− 2.7	4	8,676	se.	42	s.	30	20	7	3	2.5	
Sandusky	629	62	70	29.41	30.09	+ .03	68.4	+ 3.1	90	26	78	37	30	59	32	....	....	....	0.75	− 1.9	3	4,851	s.	33	ne.	14	23	6	1	1.4	
Toledo	628	207	246	29.41	30.09	+ .03	69.0	+ 4.9	92	11	79	40	30	59	28	58	52	63	0.38	− 2.0	2	8,974	sw.	40	s.	30	25	4	1	2.0	
Detroit	780	218	258	29.30	30.09	+ .03	68.6	+ 5.5	91	11	78	41	29	59	28	58	52	64	0.56	− 1.9	2	8,814	s.	42	w.	28	23	3	4	3.2	

TABLE I.—*Climatological data for U. S. Weather Bureau stations, September, 1908*—Continued.

Stations.	Elevation of instruments: Barometer above sea level, feet.	Elevation of instruments: Thermometers above ground.	Elevation of instruments: Anemometer above ground.	Pressure, in inches: Actual, reduced to mean of 24 hours.	Pressure, in inches: Sea level, reduced to mean of 24 hrs.	Pressure, in inches: Departure from normal.	Temperature: Mean max. + mean min. ÷ 2.	Temperature: Departure from normal.	Temperature: Maximum.	Temperature: Date.	Temperature: Mean maximum.	Temperature: Minimum.	Temperature: Date.	Temperature: Mean minimum.	Temperature: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity, per cent.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with .01, or more.	Wind: Total movement, miles.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness during daylight, tenths.	Total snowfall.
Upper Lake Region.							64.5	+ 5.6										74	2.06	— 1.2										4.4	
Alpena	609	13	92	29.39	30.06	+ 0.3	61.0	+ 3.7	93	9	72	35	3	50	37	55	53	82	1.27	— 2.2	7	6,504	nw.	51	s.	30	8	10	12	5.9	T.
Escanaba	612	40	82	29.36	30.02	+ .01	61.4	+ 4.5	80	18	70	32	29	53	29	56	54	80	1.68	— 1.9	8	6,670	s.	31	sw.	30	12	8	10	5.3	
Grand Haven	632	54	92	29.37	30.05	+ .01	65.2	+ 4.1	83	19	75	40	29	56	31	59	55	76	2.84	— 0.3	6	7,512	s.	38	w.	29	19	8	3	2.9	T.
Grand Rapids	707	121	162	29.30	30.06	+ .01	68.1	+ 6.3	92	21	80	38	29	57	32	58	53	68	1.09	— 2.0	6	6,291	sw.	32	w.	30	12	14	4	4.3	
Houghton	668	66	74	29.26	29.98	— .02	62.6	+ 6.5	89	8	73	35	29	52	39	....	....	....	4.56	+ 1.0	11	4,934	w.	30	nw.	1	12	11	7	5.0	0.2
Marquette	734	77	116	29.21	30.01	+ .01	63.9	+ 7.1	94	20	73	35	29	55	34	55	50	67	3.46	0.0	7	7,544	s.	42	sw.	8	5	17	8	5.5	T.
Port Huron	638	70	120	29.38	30.08	+ .02	65.8	+ 4.9	91	26	77	39	29	55	31	58	54	72	0.32	— 2.4	2	6,881	sw.	37	nw.	2	14	9	7	4.3	
Sault Sainte Marie	614	40	61	29.35	30.04	+ .02	61.0	+ 6.7	84	26	72	36	29	50	35	55	52	82	1.71	— 1.8	10	5,262	e.	37	nw.	28	12	13	5	4.3	T.
Chicago	823	140	310	29.20	30.07	+ .03	70.6	+ 6.0	92	11	78	36	29	63	35	63	60	74	2.09	— 0.9	7	9,105	sw.	39	w.	30	21	6	3	2.8	
Milwaukee	681	122	139	29.34	30.08	+ .05	67.8	+ 6.3	92	9	76	36	29	59	32	59	55	71	0.72	— 2.2	5	6,502	sw.	33	e.	14	15	13	2	3.1	
Green Bay	617	49	86	29.36	30.01	— .01	66.3	+ 7.2	92	20	77	32	29	56	33	58	54	73	1.15	— 1.7	6	6,740	sw.	34	w.	30	12	10	6	4.7	
Duluth	1,133	11	47	28.78	29.99	+ .01	60.4	+ 3.7	88	5	70	28	30	51	32	53	50	77	3.55	0.0	5	9,234	ne.	49	sw.	3	7	17	6	5.3	1.5
North Dakota.							61.5	+ 4.3										65	1.32	— 0.1										4.0	
Moorhead	940	8	57	28.95	29.96	.00	63.1	+ 6.5	94	8	76	28	29	50	44	54	51	76	2.11	— 0.2	6	6,083	nw.	29	nw.	5	15	9	6	3.5	
Bismarck	1,674	8	57	28.20	29.98	+ .04	62.8	+ 5.7	95	16	77	29	27	49	45	52	46	63	0.59	— 0.6	4	7,770	nw.	49	nw.	29	15	9	6	4.1	
Devils Lake	1,482	11	44	28.36	29.93	— .01	60.3	+ 4.7	94	7	73	29	28	48	41	50	44	58	0.40	— 1.0	5	9,227	nw.	40	ne.	24	17	6	7	3.9	T.
Williston	1,875	14	56	27.97	29.93	.00	59.7	+ 0.2	101	7	74	25	28	45	52	48	41	62	2.18	+ 1.3	7	7,289	e.	38	sw.	29	14	8	8	4.6	0.1
Upper Miss. Valley.							69.3	+ 4.5										70	1.83	— 1.5										3.3	
Minneapolis	......	102	208	......	......	......	68.0	.....	94	12	78	31	29	58	30	....	....	....	4.91	+ 1.2	7	9,223	s.	50	w.	22	17	8	5	3.8	T.
St. Paul	837	171	179	29.10	30.01	+ .02	67.2	+ 6.9	96	12	78	30	29	56	36	57	52	65	3.96	+ 0.5	8	7,677	s.	52	nw.	22	20	7	3	2.9	T.
La Crosse	714	10	49	29.27	30.03	+ .02	67.9	+ 6.2	93	20	80	31	29	56	33	....	....	....	2.82	— 1.3	6	3,521	s.	17	s.	8	18	3	9	4.2	
Madison	974	70	78	29.02	30.05	+ .02	67.0	+ 5.9	90	21	78	32	29	56	35	58	54	70	0.78	— 2.4	4	5,729	s.	27	s.	26	20	5	5	2.9	
Charles City	1,015	10	49	28.98	30.04	+ .04	65.9	+ 4.2	91	20	79	26	29	53	35	58	55	77	0.81	— 2.0	3	4,705	se.	26	s.	25	13	13	4	4.3	
Davenport	606	71	79	29.40	30.06	+ .03	69.4	+ 4.7	90	12	80	32	29	58	32	60	56	71	1.12	— 2.0	2	4,139	sw.	26	nw.	30	22	6	2	2.3	
Des Moines	861	84	101	29.13	30.03	+ .01	68.4	+ 3.4	92	20	80	30	29	57	31	60	56	71	0.94	— 2.1	3	4,852	s.	31	s.	25	17	9	4	3.7	
Dubuque	698	100	117	29.32	30.06	+ .03	68.1	+ 4.5	91	12	80	30	29	57	30	59	56	73	1.14	— 2.4	3	3,472	se.	24	nw.	30	17	9	4	3.7	
Keokuk	614	64	77	29.40	30.07	+ .04	70.8	+ 4.4	93	19	83	33	29	59	39	60	56	68	2.22	— 1.8	3	4,028	s.	25	se.	26	20	9	1	2.3	
Cairo	356	87	93	29.69	30.07	+ .02	73.3	+ 3.1	90	13	83	43	29	64	30	64	60	71	1.01	— 1.5	3	4,422	s.	27	nw.	27	16	6	8	3.9	
La Salle	536	56	64	29.52	30.09	+ .05	69.2	+ 5.3	94	19	82	33	29	56	39	....	....	....	1.09	— 2.1	4	4,219	sw.	26	w.	30	21	5	4	2.8	
Peoria	609	11	45	29.42	30.09	+ .05	69.0	+ 4.7	93	11	83	32	29	55	38	59	55	71	0.82	— 2.3	3	3,962	s.	22	w.	30	23	5	2	2.5	
Springfield, Ill	644	10	92	29.38	30.06	+ .01	70.2	+ 3.8	92	11	82	35	29	59	32	60	54	66	1.22	— 2.2	5	4,715	s.	24	nw.	27	23	3	4	2.5	
Hannibal	534	75	109	29.50	30.06	+ .03	70.0	+ 2.1	94	19	82	33	29	58	34	....	....	....	3.31	— 0.2	6	4,866	sw.	30	s.	23	20	6	4	3.1	
St. Louis	567	208	217	29.45	30.05	+ .01	73.4	+ 3.4	90	13	82	38	29	64	33	62	56	61	1.24	— 1.7	3	5,267	s.	30	nw.	27	18	4	8	4.2	
Missouri Valley.							69.8	+ 4.6										63	0.91	— 1.8										3.4	
Columbia, Mo	784	11	84	29.23	30.05	+ .02	70.1	+ 2.3	93	19	83	33	29	58	34	....	....	....	2.99	+ 0.1	7	4,239	se.	27	w.	26	9	13	8	5.0	
Kansas City	963	116	181	29.01	30.03	+ .01	71.9	+ 4.4	91	16	82	37	28	62	30	62	57	66	0.25	— 3.5	2	7,365	s.	41	nw.	28	18	10	2	3.2	T.
Springfield, Mo	1,324	98	104	28.67	30.06	+ .03	70.0	+ 2.1	89	15	80	35	29	61	28	61	57	73	1.87	— 1.9	9	5,864	se.	30	w.	28	15	10	5	3.7	
Iola	984	11	50	29.02	30.05	+ .04	70.4	+ 1.8	90	16	83	32	28	58	35	....	....	....	1.03	— 2.3	6	3,610	se.	26	nw.	28	10	12	8	5.0	
Topeka	......	85	89	......	......	......	70.6	+ 2.3	94	5	82	35	29	59	34	....	....	....	0.19	— 3.4	3	5,458	s.	36	nw.	28	19	8	3	2.7	
Lincoln	1,189	11	84	28.76	30.01	+ .02	70.8	+ 5.6	98	5	84	33	29	58	35	60	55	67	0.53	— 2.1	3	6,831	s.	33	s.	25	21	5	4	3.0	
Omaha	1,105	115	121	28.86	30.02	+ .02	71.6	+ 5.8	93	11	82	35	29	61	29	61	56	65	0.26	— 2.8	2	5,080	s.	27	nw.	27	22	4	4	2.7	
Valentine	2,598	47	54	27.29	29.98	+ .02	67.4	+ 5.1	99	8	83	25	27	52	46	53	43	52	0.11	— 1.7	3	7,884	s.	36	s.	24	22	7	1	2.7	T.
Sioux City	1,135	96	164	28.81	30.01	+ .03	69.2	+ 5.1	92	5	81	28	29	57	37	....	....	....	1.02	— 1.4	3	9,204	se.	37	s.	25	19	7	4	2.8	
Pierre	1,572	70	75	28.31	29.95	.00	69.4	+ 6.6	101	7	84	30	27	55	44	55	45	51	0.26	— 0.8	4	7,103	se.	40	nw.	29	17	10	3	3.1	
Huron	1,306	56	67	28.59	29.97	+ .01	67.0	+ 7.4	98	8	82	28	29	52	45	56	51	66	1.39	— 0.3	5	8,255	s.	37	s.	7	19	8	3	3.6	
Yankton	1,233	49	57	28.68	29.98	.00	69.8	+ 6.5	99	8	83	30	29	56	41	....	....	....	1.04	— 1.4	3	6,013	se.	40	s.	25	19	4	7	3.6	
Northern Slope.							59.6	+ 2.2										58	1.20	+ 0.1										4.0	
Havre	2,505	11	44	27.34	29.95	+ .01	59.0	+ 1.4	91	7	74	31	26	44	49	50	44	66	1.17	+ 0.1	8	5,851	sw.	48	sw.	7	17	10	3	3.9	0.2
Miles City	2,371	26	48	27.46	29.99	+ .04	63.8	+ 2.6	106	7	78	26	27	49	50	52	46	63	1.42	+ 0.5	7	3,551	ne.	28	ne.	3	11	15	4	3.8	1.0
Helena	4,110	8	56	25.85	30.01	+ .04	57.4	+ 1.2	87	5	69	28	26	46	40	49	43	65	1.81	+ 0.8	8	4,813	sw.	47	w.	29	12	8	10	5.0	0.3
Kalispell	2,962	8	34	26.95	29.99	+ .01	55.7	+ 1.8	88	5	70	26	25	41	47	46	39	63	2.01	+ 0.7	7	3,599	w.	24	sw.	2	16	10	4	3.5	
Rapid City	3,234	46	50	26.62	29.98	+ .02	64.9	+ 5.8	102	7	78	25	27	52	41	51	40	48	2.67	+ 1.4	6	5,331	w.	31	sw.	17	18	11	1	3.2	T.
Cheyenne	6,088	56	64	24.11	30.00	+ .04	59.1	+ 1.9	89	7	75	16	27	43	43	45	35	49	0.09	— 0.8	1	5,540	nw.	32	nw.	29	18	10	2	3.4	0.4
Lander	5,372	26	36	24.73	30.02	+ .06	56.7	+ 1.5	90	7	74	19	27	39	46	45	35	52	0.66	— 0.4	5	2,442	sw.	24	s.	17	12	12	6	4.6	3.3
Sheridan	3,790	9	47	26.13	30.00	......	58.0	......	97	7	76	20	27	40	50	47	38	58	0.67	......	8	4,115	nw.	32	nw.	29	12	11	7	4.4	1.5
Yellowstone Park	6,200	11	48	23.97	30.04	+ .07	52.4	— 1.0	83	6	65	20	27	40	39	42	34	56	0.74	— 0.3	9	5,722	sw.	41	sw.	7	11	5	14	5.4	0.8
North Platte	2,821	11	51	27.11	30.00	+ .03	67.6	+ 4.4	98	8	84	27	27	51	50	54	47	60	0.24	— 1.3	1	5,819	s.	37	nw.	25	22	7	1	2.5	
Middle Slope.							68.8	+ 1.3										63	1.90	— 0.1										3.1	
Denver	5,291	129	136	24.81	30.00	+ .04	65.0	+ 2.3	92	7	80	21	27	50	40	49	37	44	0.80	— 0.1	4	5,114	s.	39	n.	25	19	10	1	2.8	6.5
Leadville	10,248	7	....	......	......	......	......	......	....	....	....	....	....	....	....	....	....	....	......	......	....	......	....	....	....	....	....	....	....	....	
Pueblo	4,685	80	86	25.36	29.98	+ .02	65.5	+ 1.1	95	7	82	29	27	49	48	49	36	42	0.15	— 0.5	2	4,399	nw.	26	nw.	29	26	3	1	1.4	T.
Concordia	1,398	42	50	28.59	30.04	+ .05	70.1	+ 2.0	95	5	82	37	28	58	37	61	57	74	1.79	— 0.8	5	4,520	s.	34	sw.	22	14	12	4	3.8	
Dodge	2,509	44	54	27.44	30.01	+ .03	70.2	+ 2.0	101	5	84	36	28	56	45	58	52	67	1.11	— 0.7	6	6,498	se.	33	se.	25	22	4	4	2.3	
Wichita	1,358	90	120	28.64	30.06	+ .06	70.1	+ 0.3	92	5	81	37	29	60	37	62	58	75	3.21	+ 0.1	7	5,999	se.	41	sw.	16	16	8	6	4.0	
Oklahoma	1,214	10	47	28.76	30.02	+ .03	72.0	— 0.1	95	6	83	40	28	61	34	64	61	78	4.37	+ 1.6	9	7,767	s.	56	n.	22	9	14	7	4.4	
Southern Slope.							71.9	— 0.9										67	1.46	— 1.2										3.3	
Abilene	1,738	45	54	28.22	30.00	+ .04	74.3	+ 0.1	99	7	85	40	28	63	33	63	58	66	2.50	— 0.6	7	4,117	s.	24	nw.	27	11	13	6	4.4	
Amarillo	3,676	10	49	26.34	30.02	+ .06	67.6	— 0.1	97	6	81	36	28	54	35	57	52	68	1.83	— 0.5	7	7,259	s.	37	s.	25	22	7	1	2.8	
Del Rio	944	8	57	28.98	29.95	+ .01	77.8	— 1.1	104	23	91	43	29	64	38	....	....	....	0.23	— 2.7	3	4,362	se.	27	n.	27	19	8	3	3.3	
Roswell	3,578	9	57	26.43	30.02	+ .10	67.8	— 2.5	92	22	84	33	28	52	50	57	51	68	1.29	— 1.0	3	3,109	se.	26	sw.	25	22	6	2	2.7	
Southern Plateau.							70.0	— 0.5										44	0.46	— 0.6										2.3	
El Paso	3,762	110	133	26.22	29.91	+ .03	73.0	+ 0.3	93	23	86	47	28	60	37	56	44	42	T.	— 1.4	0	6,758	e.	26	ne.	14	26	4	0	1.4	
Santa Fe	7,013	33	39	23.37	29.95	+ .02	61.2	+ 0.6	85	5	74	21	27	48	42	46	34	42	0.07	— 1.6	2	5,742	ne.	31	w.	26	22	7	1	2.3	T.
Flagstaff	6,907	8	57	23.46	29.95	+ .06	55.4	— 0.1	83	6	71	25	29	40	48	44	34	36	0.99	— 1.1	6	5,133	sw.	42	sw.	24	19	7	4	3.1	
Phoenix	1,108	50	56	28.71	29.84	+ .03	81.7	+ 0.3	108	5	97	51	27	67	39	60	44	32	0.51	— 0.5	3	2,924	e.	25	sw.	7	22	7	1	2.2	
Yuma	141	9	58	29.68	29.82	+ .04	82.6	— 1.3	109	2	99	51	29	66	47	65	55	47	0.34	+ 0.2	2	4,207	w.	32	sw.	7	27	1	2	1.2	
Independence	3,910	11	42	26.00	29.95	+ .09	66.2	— 2.9	94	5	80	40	27	52	37	52	41	44	0.84	+ 0.6	6	3,897	nw.	28	se.	15	18	10	2	3.7	
Middle Plateau.							60.9	— 0.5										47	1.13	+ 0.4										3.[illegible]	
Reno	4,532	56	63	25.51	29.98	+ .03	59.6	— 0.1	91	5	76	28	25	43	43	46	34	48	0.49	+ 0.2	5	3,203	w.	25	w.	13	16	8	6	3.4	
Tonopah	6,089	12	20	24.13	29.99	......	61.5	+ 3.4	87	5	72	32	25	51	27	47	34	38	0.74	+ 0.2	6	5,767	se.	37	nw.	22	14	14	2	3.7	
Winnemucca	4,344	18	56	25.67	30.04	+ .11	58.8	— 1.7	94	5	77	19	26	41	43	46	37	53	1.23	+ 0.9	2	3,235	ne.	28	sw.	10	17	6	7	3.5	
Modena	5,479	10	43	24.66	29.96	+ .04	58.8	— 1.4	90	6	74	28	27	43	42	48	39	55	1.64	+ 1.1	7	6,401	w.	56	sw.	6	15	10	5	3.9	
Salt Lake City	4,366	105	110	25.68	30.00	+ .05	63.4	— 1.7	92	6	75	32	27	51	35	50	40	45	2.72	+ 1.9	6	3,865	se.	38	nw.	7	15	12	3	4.0	T.
Durango	6,546	18	56	23.77	30.00	+ .07	58.2	0.4	87	5	75	21	27	41	44	45	34	52	0.77	— 1.1	9	4,084	nw.	23	w.	26	15	15	0	3.1	
Grand Junction	4,608	43	51	25.45	30.00	+ .05	66.0	— 0.4	93	7	79	28	27	53	37	49	35	40	0.65	— 0.3	4	3,824	e.	32	sw.	24	20	6	4	3.0	T.
Northern Plateau.							62.3	+ 1.1										51	0.88	+ 0.1										3.[illegible]	
Baker City	3,471	48	58	26.50	30.06	+ .07	58.0	+ 1.0	94	5	72	23	26	44	40	48	40	56	1.01	+ 0.2	9	4,564	s.	23	sw.	6	20	6	4	2.[illegible]	
Boise	2,739	78	86	27.20	30.03	+ .06	62.6	+ 0.7	96	6	76	30	26	48	41	50	38	47	1.26	+ 0.8	7	3,320	nw.	40	w.	6	18	8	4	3.4	
Lewiston	757	10	51	29.23	30.03	+ .05	65.1	+ 1.6	96	5	79	34	25	51	42	....	....	....	1.60	+ 1.0	8	3,184	e.	43	w.	7	9	14	7	4.[illegible]	
Pocatello	4,477	46	54	25.56	30.04	+ .08	60.8	+ 0.1	91	6	74	28	27	47	40	47	35	46	0.94	+ 0.1	4	5,531	se.	48	sw.	7	14	15	1	3.0	T.
Spokane	1,929	101	110	27.98	30.02	+ .04	60.9	+ 2.1	91	5	75	28	25	47	44	48	36	47	0.10	— 0.9	4	3,990	sw.	24	w.	21	10	9	11	5.[illegible]	
Walla Walla	1,000	71	79	28.96	30.02	+ .02	66.4	+ 1.0	95	5	78	37	25	54	37	56	49	57	0.40	— 0.5	7	3,771	s.	22	sw.	7	17	6	7	3.9	
N. Pac. Coast Reg.							56.0	— 0.9										76	0.69	— 1.6										4.[illegible]	
Blaine	57	4	....	......	......	......	......	......	....	....	....	....	....	....	....	....	....	....	......	......	....	......	....	....	....	....	....	....	....	....	
North Head	211	11	56	29.90	30.12	+ .09	54.2	— 2.0	65	30	57	44	25	51	10	52	50	86	0.53	— 1.3	8	8,121	nw.	46	se.	7	10	13	7	5.2	
Port Crescent	259	12	29	29.84	30.13	+ .11	50.2	— 2.3	69	4	58	30	25	43	25	....	....	....	0.57	— 1.7	5	3,133	nw.	19	nw.	23	5	16	9	5.7	
Seattle	123	185	224	30.00	30.13	+ .12	57.1	— 0.8	77	1	65	36	25	49	25	52	48	75	0.23	— 1.7	3	4,125	n.	29	s.	9	3	18	9	6.1	

TABLE I.—*Climatological data for U. S. Weather Bureau stations, September, 1908*—Continued.

Stations.	Elevation of instruments. Barometer above sea level, feet.	Thermometers above ground.	Anemometer above ground.	Pressure, in inches. Actual, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hrs.	Departure from normal.	Temperature of the air, in degrees Fahrenheit. Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity, per cent.	Precipitation, in inches. Total.	Departure from normal.	Days with .01, or more.	Wind. Total movement, miles.	Prevailing direction.	Maximum velocity. Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness during daylight, tenths.	Total snowfall.
N. P. Coast Reg—Cont.																															
Tacoma	213	113	120	29.87	30.10	+ .08	57.0	— 0.6	79	4	66	35	25	48	31	52	47	73	0.18	— 2.3	3	3,018	n.	22	sw.	7	12	10	8	5.0	
Tatoosh Island	86	7	57	30.02	30.12	+ .11	52.6	— 0.4	66	10	57	40	25	48	14	50	48	88	2.65	— 3.5	12	7,214	s.	46	s.	7	6	11	13	6.2	
Portland, Oreg	153	68	106	29.93	30.09	+ .06	60.0	— 0.6	86	4	71	35	24	49	33	54	49	72	0.23	— 1.6	3	3,403	nw.	21	nw.	23	17	7	6	3.9	
Roseburg	510	9	57	29.53	30.08	+ .06	60.6	+ 0.1	93	3	77	30	25	44	45	52	45	65	0.43	— 0.6	6	2,179	nw.	17	nw.	23	20	8	2	2.5	
Mid. Pac. Coast Reg.							64.9	+ 0.5										59	0.06	— 0.5										4.1	
Eureka	62	62	80	29.99	30.06	+ .05	54.2	— 0.7	69	29	60	42	18	48	21	51	49	87	0.02	— 1.1	2	4,612	n.	44	n.	24	12	9	9	5.0	
Mount Tamalpais	2,375	11	18	27.55	29.99	+ .05	66.2	......	88	2	74	44	16	58	22	51	37	41	0.02	— 0.4	2	9,969	nw.	62	nw	14	23	3	4	2.3	
Point Reyes Light	490	7	18	29.43	29.95	......	55.8	......	79	29	61	48	1	51	26	....	....	....	0.20	......	2	13,257	n.	63	nw.	16	13	1	16	5.9	
Red Bluff	332	50	56	29.63	29.90	— .03	74.2	+ 0.3	101	5	89	50	17	60	38	57	43	40	0.01	— 0.8	1	3,834	se.	40	n.	24	19	8	3	2.6	
Sacramento	69	106	117	29.85	29.92	+ .03	71.2	+ 2.1	100	12	86	50	18	57	39	57	46	47	0.05	— 0.3	1	5,555	s.	24	nw.	24	20	8	2	2.4	
San Francisco	155	200	204	29.81	29.97	+ .03	60.5	+ 1.2	89	29	68	50	2	53	30	54	50	78	0.13	— 0.2	4	6,245	w.	30	w.	2	13	12	5	4.8	
San Jose	141	78	88	29.82	29.97	......	64.5	— 0.2	94	11	79	42	26	50	44	....	....	....	0.09	— 0.2	2	3,551	nw.	20	nw.	15	18	8	4	3.5	
Southeast Farallon	30	9	17	29.96	30.00	......	54.0	......	70	27	57	46	25	51	18	....	....	....	0.07	— 0.2	3	9,251	nw.	43	nw.	7	9	3	18	6.5	
S. Pac. Coast Reg.							68.5	+ 1.2										66	0.63	+ 0.4										3.2	
Fresno	330	67	70	29.57	29.92	+ .05	74.5	+ 0.2	103	3	90	48	25	59	45	58	44	43	0.15	— 0.1	1	3,032	w.	16	nw.	15	21	6	3	2.8	
Los Angeles	338	159	191	29.56	29.92	+ .04	69.8	+ 3.3	96	12	80	54	17	60	34	60	55	70	1.22	+ 1.2	4	4,247	sw.	38	s.	22	16	10	4	3.5	
San Diego	87	94	102	29.83	29.92	+ .03	66.6	— 0.3	84	28	72	52	27	61	29	60	57	75	0.20	+ 0.1	3	4,309	nw.	23	nw.	21	22	6	2	2.7	
San Luis Obispo	201	47	54	29.76	29.98	+ .05	63.2	+ 1.7	94	29	76	45	9	51	44	54	50	74	0.84	+ 0.4	3	3,224	nw.	19	n.	8	14	11	5	4.0	
West Indies.																															
Grand Turk	11	6	20	......	......	......	......	......	....	....	....	....	....	....	....	....	....	....	......	......	....	......	....	....	......	....	....	....	....	....	
San Juan	82	48	90	29.84	29.92	— .02	81.0	......	91	16	87	71	10	75	15	76	74	80	8.19	+ 3.1	16	8,000	se.	40	nw.	10	5	17	8	6.0	
Panama.																															
Christobal	74	....	....	29.84	29.86	......	79.3	......	90	10	84	72	8	74	16	75	75	90	11.57	......	26	3,864	se.	32	sw.	8	2	13	15	7.0	
Bas Obispo	40	....	....	29.69	29.86	......	78.4	......	89	22	85	69	20	72	19	74	74	95	6.70	......	25	2,550	nw.	18	se.	9	0	5	25	8.3	
Ancon	....	....	....	29.77	29.85	......	79.6	......	91	4	86	70	3	73	18	75	74	87	5.93	......	20	4,038	nw.	18	nw.	26	2	14	14	7.4	
Alhajuela	....	....	....	......	......	......	78.4	......	90	14	85	70	3	72	20	....	....	....	13.45	......	24	946	ne.	15	ne.	23	....	....	....	....	
Bohio	....	....	....	......	......	......	79.4	......	91	10	87	70	7	72	21	....	....	....	8.74	......	27	1,425	e.	17	sw.	29	....	....	....	....	
Gatun	....	....	....	......	......	......	78.9	......	89	7	86	70	8	72	18	....	....	....	8.52	......	26	2,344	s.	16	nw.	4	....	....	....	....	

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for storms in which the rate of fall equaled or exceeded 0.25 in any 5 minutes, or 0.80 inch in 1 hour, during September, 1908, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration. From—	To—	Total amount of precipitation.	Excessive rate. Began—	Ended—	Amount before excessive began.	Depths of precipitation (in inches) during periods of time indicated. 5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex	2			0.68						0.37											
Albany, N. Y	28-29			0.61				0.24													
Alpena, Mich	18			0.28					0.20												
Amarillo, Tex	25			0.32				0.10													
Anniston, Ala	4	3:10 p. m.	6:00 p. m.	0.63	4:35 p. m.	5:05 p. m.	0.01	0.09	0.22	0.25	0.34	0.42	0.50								
Do	5	11:32 a. m.	12:50 p. m.	0.74	12:03 p. m.	12:23 p. m.	0.13	0.12	0.39	0.52	0.58										
Do	5	2:25 p. m.	5:20 p. m.	1.95	3:20 p. m.	3:54 p. m.	0.02	0.50	1.01	1.19	1.53	1.67	1.76	1.81							
Asheville, N. C	5	9:50 a. m.	8:20 p. m.	1.58	2:11 p. m.	2:42 p. m.	0.72	0.06	0.18	0.27	0.43	0.56	0.68	0.72							
Atlanta, Ga	4	12:20 p. m.	1:15 p. m.	0.81	12:32 p. m.	12:57 p. m.	0.01	0.17	0.32	0.53	0.58	0.80									
Do	4	7:25 p. m.	8:10 p. m.	0.55	7:31 p. m.	7:48 p. m.	0.01	0.19	0.35	0.48	0.52										
Atlantic City, N. J	5-6	D. N. p. m.	9:20 a. m.	3.16	7:00 a. m.	8:48 a. m.	0.87	0.06	0.18	0.31	0.41	0.57	0.78	1.00	1.14	1.19	1.21	1.24	1.67	2.09	2.28
Augusta, Ga	27	1:50 p. m.	6:15 p. m.	0.86	3:18 p. m.	3:36 p. m.	0.13	0.24	0.47	0.59	0.62										
Baker City, Oreg	7			0.24														0.22			
Baltimore, Md	28	6:05 p. m.	10:00 p. m.	1.01	7:35 p. m.	8:27 p. m.	0.01	0.05	0.10	0.14	0.26	0.31	0.36	0.43	0.58	0.76	0.83	0.92			
Bentonville, Ark	15	2:15 p. m.	3:40 p. m.	0.46	2:46 p. m.	2:58 p. m.	0.02	0.13	0.34	0.42											
Do	16	1:00 p. m.	2:10 p. m.	0.62	1:17 p. m.	1:43 p. m.	0.02	0.16	0.22	0.35	0.40	0.54	0.55								
Do	16	3:20 p. m.	5:45 p. m.	0.58	3:38 p. m.	3:56 p. m.	0.02	0.10	0.22	0.38	0.45										
Binghamton, N. Y	6	4:35 p. m.	5:45 p. m.	0.33	4:48 p. m.	4:58 p. m.	0.01	0.20	0.30												
Birmingham, Ala	28			0.32														0.31			
Bismarck, N. Dak	18			0.25									0.23								
Block Island, R. I	2			0.52														0.14			
Boise, Idaho	7			0.68														0.34			
Boston, Mass	29			0.45														0.33			
Buffalo, N. Y	1			0.14					0.11												
Burlington, Vt	28-29	8:20 p. m.	D. N. a. m.	0.64	12:05 a. m.	12:20 a. m.	0.05	0.11	0.26	0.39											
Cairo, Ill	27			0.89														0.46			
Canton, N. Y	6			0.50														0.49			
Charleston, S. C	27			0.73														0.41			
Charlotte, N. C	5			0.97														0.56			
Chattanooga, Tenn	5	4:40 a. m	3:16 p. m.	1.39	8:25 a. m.	8:58 a. m.	0.19	0.22	0.35	0.50	0.55	0.65	0.74	0.78							
Cheyenne, Wyo	25			0.09														*			
Chicago, Ill	27-28			1.33														0.32			
Cincinnati, Ohio	28			0.26														0.13			
Cleveland, Ohio	28			0.34														0.12			
Columbia, Mo	26-27	6:15 p. m.	5:50 p. m.	2.15	8:17 p. m.	8:37 p. m.	0.39	0.14	0.27	0.43	0.50										
					11:34 p. m.	11:49 p. m.	1.24	0.13	0.28	0.43											
Columbia, S. C	5	7:42 p. m.	8:45 p. m.	0.46	7:59 p. m.	8:14 p. m.	0.02	0.07	0.27	0.35											
Columbus, Ohio	28			0.38														0.19			
Concord, N. H	28-29			0.42														0.15			
Concordia, Kans	22	1:56 p. m.	3:28 p. m.	1.22	2:38 p. m.	3:13 p. m.	0.02	0.05	0.21	0.42	0.72	1.00	1.00	1.16							
Corpus Christi, Tex	3	7:39 a. m.	9:03 a. m.	0.44	7:45 a. m.	7:56 a. m.	0.01	0.21	0.37	0.40											
Do	16	6:32 a. m.	4:38 p. m.	0.69	11:19 a. m.	11:36 a. m.	0.12	0.08	0.17	0.44	0.51										
Davenport, Iowa	27			1.08														0.35			
Del Rio, Tex	10			0.12														0.12			
Denver, Colo	25-26			0.76														*			
Des Moines, Iowa	26			0.76														0.47			
Detroit, Mich	28			0.53														0.21			
Devils Lake, N. Dak	25			0.34														0.18			
Dodge, Kans	25	6:12 p. m.	8:05 p. m.	0.57	7:04 p. m.	7:22 p. m.	0.06	0.11	0.22	0.30	0.44										
Dubuque, Iowa	27			1.04														0.18			
Duluth, Minn	24	3:35 a. m.	8:20 a. m.	1.90	4:04 a. m.	5:33 a. m.	0.07	0.07	0.16	0.29	0.33	0.35	0.35	0.36	0.51	0.68	0.76	0.78	1.04	1.35	
Do	26	7:40 a. m.	3:00 p. m.	0.86	10:45 a. m.	11:04 a. m.	0.23	0.07	0.10	0.26	0.46										
Durango, Colo	24			0.49														0.20			
Eastport, Me	29			1.09														0.53			

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, etc.*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive began.	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Elkins, W. Va.	2			0.17														0.17			
El Paso, Tex.	1,24,25			T.														T.			
Erie, Pa.	29			0.34														0.20			
Escanaba, Mich	19			0.21														0.17			
Eureka, Cal.	2, 15			0.01														0.01			
Evansville, Ind	27			1.10														0.37			
Flagstaff, Ariz.	7			0.40														0.26			
Fort Smith, Ark.	22			1.12														0.81			
Fort Worth, Tex	17	11:47 a. m.	3:35 p. m.	1.76	1:09 p. m.	2:04 p. m.	0.25	0.15	0.19	0.26	0.47	0.66	0.82	0.92	0.95	1.04	1.29	1.51			
Do	23	2:08 a. m.	5:55 a. m.	1.08	2:25 a. m.	2:50 a. m.	0.05	0.16	0.36	0.60	0.71	0.79									
Fresno, Cal.	23			3.15														0.07			
Galveston, Tex	10–11	8:30 p. m.	11:30 a. m.	3.12	2:44 a. m.	3:44 a. m.	0.69	0.06	0.10	0.17	0.22	0.32	0.44	0.54	0.57	0.58	0.64	0.85			
					5:36 a. m.	5:49 a. m.	2.31	0.28	0.42	0.49											
Do	12	4:05 a. m.	9:57 a. m.	1.74	4:21 a. m.	4:59 a. m.	0.01	0.22	0.46	0.66	0.84	1.03	1.22	1.29	1.33						
Do	16–17	10:10 p. m.	2:40 p. m.	6.54														*			
Do	21	6:50 a. m.	7:35 a. m.	0.64	6:53 a. m.	7:17 a. m.	0.02	0.06	0.12	0.26	0.51	0.60									
		11:30 a. m.	1:30 p. m.	0.61	11:41 a. m.	11:52 a. m.	0.03	0.33	0.56	0.57											
Do	23	7:56 a. m.	9:40 a. m	0.64	8:03 a. m.	8:22 a. m.	0.02	0.10	0.19	0.46	0.53										
Grand Haven, Mich	1	D. N. a. m.	D. N. a. m.	0.79	1:31 a. m.	2:00 a. m.	0.01	0.12	0.21	0.21	0.42	0.69	0.77								
Grand Junction, Colo.	8			0.39														0.11			
Grand Rapids, Mich.	28			0.66														0.20			
Green Bay, Wis	27–28			0.91														0.18			
Hannibal, Mo	23	6:08 p. m.	8:40 p. m.	0.77	6:16 p. m.	6:37 p. m.	0.01	0.22	0.39	0.51	0.64	0.68									
Harrisburg, Pa	28	6:23 p. m.	8:32 p. m.	0.54	6:26 p. m.	6:46 p. m.	0.01	0.09	0.19	0.31	0.40										
Hartford, Conn	28–29			1.10														*			
Hatteras, N. C.	27	7:40 p. m.	11:35 p. m.	1.26	7:44 p. m.	8:29 p. m.	0.01	0.09	0.24	0.33	0.34	0.37	0.57	0.61	0.69	0.80					
Havre, Mont.	17			0.29														0.06			
Helena, Mont	17			0.98														0.37			
Houghton, Mich	27			1.40														0.19			
Huron, S. Dak	25			1.14														0.75			
Indianapolis, Ind.	28			0.99														0.39			
Iola, Kans.	23			0.22														0.15			
Jacksonville, Fla.	6	12:20 p. m.	2:45 p. m.	1.19	12:23 p. m.	12:47 p. m.	0.01	0.32	0.75	0.95	0.99	1.06									
Do	9	D. N. a. m.	D. N. p. m.	6.10	9:43 a. m.	10:19 a. m.	1.34	0.08	0.16	0.27	0.40	0.59	0.74	0.84	0.89						
Do	10	8:55 a. m.	5:45 p. m.	4.92	10:53 a. m.	11:42 a. m.	0.27	0.19	0.32	0.51	0.67	0.88	1.10	1.32	1.47	1.57	1.66				
					2:38 p. m.	3:30 p. m.	2.29	0.25	0.57	0.85	0.94	1.07	1.21	1.31	1.51	1.91	2.15	2.21			
Do	10–11	D. N. p. m.	D. N. a. m.	1.77	11:15 p. m.	12:15 a. m.	0.03	0.08	0.20	0.28	0.34	0.39	0.51	0.62	0.86	1.07	1.28	1.61			
Do	25–26	8:20 p. m.	5:15 p. m.	3.07	6:50 a. m.	7:19 a. m.	1.79	0.07	0.12	0.25	0.47	0.69	0.78								
Jupiter, Fla.	4	6:42 a. m.	7:48 a. m.	0.63	7:02 a. m.	7:32 a. m.	0.08	0.18	0.32	0.36	0.39	0.45	0.52								
Do	9	5:45 p. m.	9:00 p. m.	0.49	5:47 p. m.	5:57 p. m.	0.01	0.27	0.42												
Do	17	1:15 a. m.	5:00 a. m.	0.71	4:13 a. m.	4:23 a. m.	0.32	0.17	0.36												
Kalispell, Mont.	15			0.59														0.41			
Kansas City, Mo.	27			0.21														0.07			
Keokuk, Iowa	27			1.44														0.58			
Key West, Fla	21	5:06 p. m.	8:25 p. m.	1.45	5:14 p. m.	5:34 p. m.	0.03	0.18	0.35	0.67	0.93										
Do	22	8:07 a. m.	11:50 a. m.	2.65	8:50 a. m.	10:21 a. m.	0.14	0.22	0.35	0.58	0.81	1.03	1.22	1.40	1.57	1.60	1.61	1.71	2.14	2.42	
Knoxville, Tenn.	5			1.54														0.55			
La Crosse, Wis	26			1.25														0.35			
Lander, Wyo.	25			0.42														0.09			
La Salle, Ill.	22			0.49														0.48			
Lewiston, Idaho	14			0.49														0.16			
Lexington, Ky.	28			0.38														0.29			
Lincoln, Nebr.	26			0.50														0.19			
Little Rock, Ark.	27			1.77														0.76			
Los Angeles, Cal.	24			0.81														0.32			
Louisville, Ky.	28			0.37														0.21			
Lynchburg, Va.	5			1.13														0.31			
Macon, Ga	4	3:50 p. m.	5:40 p. m.	0.93	3:59 p. m.	4:24 p. m.	0.01	0.17	0.52	0.70	0.80	0.85									
Madison, Wis.	27			0.57														0.11			
Marquette, Mich.	27			1.03														0.37			
Memphis, Tenn	27			0.57														0.42			
Meridian, Miss.	21	3:48 p. m.	6:10 p. m.	0.91	3:50 p. m.	4:15 p. m.	0.01	0.32	0.52	0.68	0.78	0.84									
Milwaukee, Wis.	27			0.33														0.11			
Minneapolis, Minn	12–13	6:20 p. m.	6:30 a. m.	3.11	6:32 p. m.	6:49 p. m.	0.01	0.09	0.23	0.34	0.43										
					8:54 p. m.	9:32 p. m.	0.59	0.06	0.11	0.28	0.62	0.89	0.93	1.05	1.10						
					10:15 p. m.	10:52 p. m.	1.73	0.17	0.23	0.27	0.39	0.47	0.54	0.60	0.64						
Mobile, Ala.	4	3:00 p. m.	7:40 p. m.	0.74	3:17 p. m.	3:32 p. m.	0.03	0.13	0.31	0.44											
Do	5	D. N. a. m.	8:00 a. m.	3.74	12:59 a. m.	1:43 a. m.	0.02	0.23	0.35	0.42	0.44	0.45	0.73	0.95	1.02	1.11					
					3:27 a. m.	3:45 a. m.	1.51	0.17	0.35	0.45	0.58										
					4:31 a. m.	5:41 a. m.	2.22	0.11	0.32	0.46	0.51	0.54	0.58	0.54	0.73	0.83	0.90	0.93	1.23		
Do	5	8:30 a. m.	10:30 a. m.	0.76	8:41 a. m.	9:03 a. m.	0.02	0.15	0.46	0.59	0.65	0.69									
Modena, Utah	8			0.40														0.27			
Montgomery, Ala	19			0.49														0.48			
Moorhead, Minn	17	3:15 p. m.	6:25 p. m.	0.75	3:25 p. m.	3:53 p. m.	0.04	0.09	0.21	0.39	0.52	0.63	0.66								
Mount Tamalpais, Cal.	15			0.01														0.01			
Mount Weather, Va.	28			1.83														0.78			
Nantucket, Mass.	2	8:35 a. m.	4:40 p. m.	2.10	1:36 p. m.	2:41 p. m.	0.79	0.14	0.20	0.22	0.24	0.29	0.40	0.54	0.66	0.71	0.77	0.96	1.07		
Nashville, Tenn.	27–28			0.70														0.48			
New Haven, Conn.	29			0.62														0.45			
New Orleans, La	11	10:50 a. m.	5:05 p. m.	1.97	12:30 p. m.	1:15 p. m.	0.36	0.13	0.45	0.57	0.78	1.08	1.30	1.36	1.42	1.52					
Do	17–18	8:30 p. m.	4:55 p. m.	1.80	8:06 a. m.	8:29 a. m.	0.75	0.11	0.24	0.32	0.42	0.50									
Do	22	11:32 a. m.	1:30 p. m.	1.14	11:43 a. m.	12:18 p. m.	0.02	0.18	0.37	0.48	0.59	0.85	0.98	1.05							
Do	25	11:48 a. m.	9:15 p. m.	1.57	11:53 a. m.	12:30 p. m.	0.03	0.36	0.36	0.53	0.66	0.91	1.09	1.23							
New York, N. Y.	28			0.45														0.42			
Norfolk, Va.	6			0.42														0.38			
Northfield, Vt	29			0.19														0.18			
North Head, Wash.	6			0.21														0.20			
North Platte, Nebr	25			0.24														0.11			
Oklahoma, Okla.	3–4	10:10 p. m.	4:30 a. m.	1.97	1:52 a. m.	2:32 a. m	1.05	0.06	0.14	0.26	0.35	0.50	0.58	0.64	0.69						
Do	22–23	8:20 p. m.	D. N. a. m.	1.50	8:28 p. m.	9:08 p. m.	0.02	0.05	0.18	0.38	0.58	0.83	1.02	1.18	1.27						
Omaha, Nebr.	26			0.20														*			
Oswego, N. Y.	28	6:37 p. m.	10:00 p. m.	1.13	6:47 p. m.	7:19 p. m.	0.01	0.28	0.48	0.54	0.61	0.67	0.74	0.77							
Palestine, Tex	13			0.58														0.50			
Parkersburg, W. Va.	6	7:33 p. m.	7:50 p. m.	0.48	7:33 p. m.	9:44 p. m.	0.00	0.22	0.47	0.48											
Pensacola, Fla.	5	6:00 a. m.	6:40 a. m.	0.71	6:13 a. m.	6:27 a. m.	0.01	0.24	0.54	0.68											
Peoria, Ill	27			0.80														0.18			
Philadelphia, Pa	28			0.67														0.36			
Phoenix, Ariz	7			0.30														0.16			
Pierre, S. Dak	28			0.15														0.07			
Pittsburg, Pa.	28			0.53														0.29			
Pocatello, Idaho	17			0.69														0.28			
Point Reyes Light, Cal.	20			0.19														0.04			
Port Huron, Mich.	28			0.25														0.11			
Portland, Me	29			0.59														0.41			

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, etc.*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive began.	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Portland, Oreg	19			0.14														0.14			
Providence, R. I	29			0.41														0.22			
Pueblo, Colo	26			0.14														0.03			
Raleigh, N. C	5	2:25 p. m.	D. N.	2.83	3:08 p. m.	4:03 p. m.	0.01	0.11	0.17	0.20	0.22	0.30	0.38	0.55	0.74	0.95	1.17	1.29			
					4:23 p. m.	5:33 p. m.	1.38	0.07	0.17	0.24	0.27	0.29	0.34	0.45	0.52	0.61	0.64	0.68	1.04		
Rapid City, S. Dak	13	8:20 p. m.	D. N. p. m.	1.00	8:32 p. m.	8:58 p. m.	0.01	0.07	0.21	0.35	0.42	0.49									
Do	17	6:30 p. m.	7:00 p. m.	1.04	6:33 p. m.	6:52 p. m.	0.01	0.45	0.61	0.83	1.02										
Red Bluff, Cal	16			0.01														0.01			
Reno, Nev	16			0.28														0.22			
Richmond, Va	5–6	5:22 p. m.	4:00 a. m.	2.01	12:15 a. m.	12:30 a. m.	0.81	0.10	0.42	0.65											
Rochester, N. Y	1–2	11:00 p. m.	1:15 a. m.	0.86	11:02 p. m.	11:25 p. m.	0.01	0.19	0.31	0.53	0.67	0.75									
Roseburg, Oreg	19			0.24														0.11			
Roswell, N. Mex	1			1.12														0.63			
Sacramento, Cal	15			0.05														0.03			
St. Louis, Mo	27			0.93														0.24			
St. Paul, Minn	12	6:38 p. m.	11:45 p. m.	1.93														*			
Salt Lake City, Utah	23	7:40 p. m.	11:15 p. m.	0.50	9:35 p. m.	9:50 p. m.	0.07	0.21	0.32	0.36											
San Antonio, Tex	9	12:15 p. m	2:00 p. m.	1.56	12:39 p. m.	1:38 p. m.	0.01	0.32	0.39	0.42	0.50	0.59	0.75	0.79	0.91	1.23	1.37	1.52			
San Diego, Cal	6			0.12														0.10			
Sand Key, Fla	7	5:40 p. m.	10:45 p. m.	1.40	5:55 p. m.	6:25 p. m.	0.03	0.12	0.36	0.66	0.97	1.18	1.25								
Sandusky, Ohio	1			0.46														0.46			
San Francisco, Cal	16			0.05														0.04			
San Jose, Cal	15			0.05														0.05			
San Luis Obispo, Cal	22			0.26														0.17			
Santa Fe, N. Mex	25			0.05														*			
Sault Sainte Marie, Mich	28			0.56														0.36			
Savannah, Ga	4	7:38 a. m.	8:35 a. m.	1.18	7:41 a. m.	8:18 a. m.	0.01	0.23	0.38	0.55	0.69	0.86	0.95	1.11	1.16						
Do	25–26	D. N. p. m.	2:25 p. m.	2.97	4:29 a. m.	4:39 a. m.	0.34	0.26	0.35												
Do	26–27	4:40 p. m.	D. N. a. m.	1.62	3:33 a. m.	3:52 a. m.	0.62	0.12	0.34	0.62	0.76										
Scranton, Pa	28	3:00 p. m.	10:40 p. m.	1.50	7:17 p. m.	7:52 p. m.	0.14	0.09	0.13	0.18	0.23	0.35	0.37	0.70							
Seattle, Wash	14			0.18																	
Sheridan, Wyo	24			0.19														0.06			
Shreveport, La	18–19	6:25 p. m.	9:40 a. m.	1.36	6:08 a. m.	6:20 a. m.	0.35	0.11	0.30	0.36											
Do	24	D. N. a. m.	7:50 a. m	1.56	5:23 a. m.	6:13 a. m.	0.24	0.12	0.20	0.32	0.41	0.54	0.59	0.59	0.62	0.73	0.79				
Sioux City, Iowa	26			0.95														0.55			
Southeast Farallon, Cal	20			0.05														0.01			
Spokane, Wash	14			0.03														0.03			
Springfield, Ill	22			0.67														0.25			
Springfield, Mo	26			0.38														0.35			
Syracuse, N. Y	28			0.69														0.58			
Tacoma, Wash	7			0.15														0.05			
Tampa, Fla	4–5	8:00 p. m.	D. N. a. m.	1.69	11:35 p. m.	12 mid'nt.	0.07	0.28	0.59	0.82	0.95	1.01									
Do	19	11:28 a. m.	2:35 p. m.	0.89	12:11 p. m.	12:39 p. m.	0.05	0.20	0.39	0.44	0.53	0.69	0.75								
Tatoosh Island, Wash	7			0.45														0.21			
Taylor, Tex	23	6:30 p. m.	7:35 p. m.	2.46	6:38 p. m.	7:23 p. m.	0.01	0.07	0.11	0.20	0.59	1.12	1.68	2.09	2.37	2.43					
Thomasville, Ga	20–21	5:40 p. m.	7:12 a. m.	1.25	7:16 p. m.	7:33 p. m.	0.41	0.13	0.25	0.36	0.41										
Toledo, Ohio	28			0.37														0.17			
Tonopah, Nev	13			0.32														0.16			
Topeka, Kans	26			0.13														0.05			
Vicksburg, Miss	27			0.24														0.22			
Walla Walla, Wash	7			0.16														0.08			
Washington, D. C	28	8:56 a. m.	1:04 p. m.	0.68	12:37 p. m.	12:57 p. m.	0.16	0.05	0.12	0.25	0.51										
Do	28	7:21 p. m.	10:00 p. m.	0.75	7:28 p. m.	7:50 p. m.	0.01	0.08	0.26	0.40	0.53										
Wichita, Kans	3	4:45 p. m.	8:00 p. m.	0.78	5:06 p. m.	5:23 p. m.	0.06	0.09	0.35	0.48	0.53										
Do	14	6:40 a. m.	5:28 p. m.	1.45	8:57 a. m.	9:49 a. m.	0.39	0.11	0.20	0.27	0.34	0.48	0.53	0.55	0.66	0.73	0.85	0.91			
Williston, N. Dak	18			0.79														0.21			
Wilmington, N. C	6			0.64														0.25			
Winnemucca, Nev	7			1.06														0.41			
Wytheville, Va	7			0.60														0.60			
Yankton, S. Dak	26			0.85														0.30			
Yellowstone Park, Wyo	17			0.28														0.12			
Yuma, Ariz	2			0.69								0.19									

*Partly estimated.

TABLE III.—*Data furnished by the Canadian Meteorological Service, September, 1908.*

Stations.	Pressure.			Temperature.				Precipitation.		
	Actual, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean.	Departure from normal.	Mean maximum.	Mean minimum.	Total.	Departure from normal.	Total snowfall.
	Ins.	*Ins.*	*Ins.*	°	°	°	°	*Ins.*	*Ins.*	*Ins.*
St. Johns, N. F	29.80	29.94	−.03	56.2	+ 2.2	64.2	48.2	1.38	−2.33	....
Sydney, C. B. I	29.98	30.02	+.01	60.2	+ 3.7	69.1	51.4	2.10	−1.18	....
Halifax, N. S	29.95	30.05	+.01	59.6	+ 2.0	69.8	49.3	1.42	−2.29	....
Grand Manan, N. B	29.99	30.04	+.01	60.4	+ 4.3	68.1	52.7	1.76	−1.41	....
Yarmouth, N. S	30.01	30.08	+.03	56.5	+ 0.4	64.2	48.7	2.29	−1.16	....
Charlottetown, P. E. I	29.97	30.01	.00	60.5	+ 3.2	68.1	52.9	1.81	−1.59	....
Chatham, N. B	29.97	29.99	−.01	60.3	+ 4.9	71.2	49.3	0.89	−1.82	....
Father Point, Que	29.96	29.98	.00	52.4	+ 2.0	60.3	44.1	1.48	−1.65	....
Quebec, Que	29.71	30.03	+.02	59.4	+ 4.3	69.0	49.9	1.48	−2.19	....
Montreal, Que	29.84	30.04	.00	63.6	+ 5.2	72.2	55.0	1.80	−1.50	....
Rockliffe, Ont	29.44	30.04	+.01	58.0	+ 2.8	71.0	45.0	2.15	−1.13	....
Ottawa, Ont	29.80	......	......	63.1	+ 5.7	75.2	51.0	1.18	−1.51	....
Kingston, Ont	29.79	30.10	+.06	63.5	+ 3.5	71.6	55.4	1.20	−1.60	....
Toronto, Ont	29.70	30.07	+.01	63.7	+ 4.7	75.4	52.0	1.29	−1.96	....
White River, Ont	......	......	......	......	......	......	......	......	......	....
Port Stanley, Ont	29.46	30.10	+.04	61.6	+ 2.1	71.7	51.5	0.52	−2.21	....
Southampton, Ont	29.36	......	......	63.7	+ 6.2	74.3	53.0	1.02	......	T.
Parry Sound, Ont	29.38	30.06	+.03	62.6	+ 6.6	73.9	51.4	3.38	−0.29	....
Port Arthur, Ont	29.26	29.97	−.01	58.5	+ 6.3	68.9	48.2	1.08	−2.40	T.
Winnipeg, Man	29.11	29.93	−.01	58.3	+ 5.8	70.1	46.6	1.89	−0.14	2.3
Minnedosa, Man	28.14	29.94	.00	55.1	+ 4.6	66.9	43.3	1.53	+0.17	2.9
Qu' Appelle, Assin	27.67	29.90	−.02	54.1	+ 3.0	66.4	41.7	0.69	−0.64	....
Medicine Hat, Alberta	27.67	29.92	.00	60.1	+ 5.1	74.1	46.1	T.	−1.18	....
Swift Current, Sask	27.40	29.95	+.03	56.3	+ 3.2	69.3	43.3	0.34	−0.88	....
Calgary, Alberta	26.40	29.90	−.02	53.3	+ 3.5	67.0	39.6	0.58	−0.78	5.6
Banff, Alberta	25.39	29.95	+.02	49.7	+ 3.9	60.9	38.5	1.41	−0.26	1.0
Edmonton, Alberta	27.60	29.88	−.02	51.5	+ 2.2	65.1	37.9	0.59	−0.74	0.5
Prince Albert, Sask	......	......	......	......	......	......	......	......	......	....
Battleford, Sask	28.18	29.91	+.01	53.2	+ 1.4	66.7	39.8	1.23	−0.02	....
Kamloops, B. C	28.69	29.95	−.02	57.9	+ 0.5	69.9	45.9	0.10	−0.75	....
Victoria, B. C	29.99	30.09	+.08	53.6	− 1.2	61.9	45.3	0.62	−1.54	....
Barkerville, B. C	25.68	29.98	.00	45.0	− 1.7	56.0	34.0	7.06	+4.15	....
Hamilton, Bermuda	29.90	30.06	−.01	78.0	+ 0.6	83.3	72.8	5.68	−0.83	....
Dawson, Yukon	......	......	......	......	......	......	......	......	......	....

TABLE IV.—*Heights of rivers referred to zeros of gages, September, 1908.*

Stations.	Distance to mouth of river.	Flood stage on gage.	Highest water.		Lowest water.		Mean stage.	Monthly range.
			Height.	Date.	Height.	Date.		
	Miles.	*Feet.*	*Feet.*		*Feet.*		*Feet.*	*Feet.*
Republican River.								
Clay Center, Kans	42	18	7.8	1,2	5.8	30	6.5	2.6
Smoky Hill-Kansas River.								
Abilene, Kans	254	22	2.7	1,2	1.6	16,21,25, 26,29,30	2.0	1.1
Manhattan, Kans	160	18	6.2	1	2.8	30	3.6	3.4
Topeka, Kans	87	21	9.5	1	6.1	25,26,29,30	7.0	3.4
Missouri River.								
Townsend, Mont	2,504	11	4.8	18,19,21-23,28-30	4.5	1-14	4.6	0.3
Fort Benton, Mont	2,285	12	1.8	26	1.1	17,18	1.4	0.7
Wolfpoint, Mont	1,952	17	− 1.6	22-25	− 0.7	28-30	−1.3	0.9
Bismarck, N. Dak	1,309	14	3.6	1	2.0	18,19,24,25	2.6	1.6
Pierre, S. Dak	1,114	14	2.7	2	1.0	25-30	1.7	1.7
Sioux City, Iowa	784	17	6.3	4	4.6	26,27	5.5	1.7
Blair, Nebr	705	15	6.3	5,6	5.5	24-30	5.9	0.8
Omaha, Nebr	669	18	9.8	1	8.4	25-30	9.0	1.4
St. Joseph, Mo	481	10	3.4	1	1.1	26-30	2.1	2.3
Kansas City, Mo	388	21	10.7	1	6.8	30	8.3	3.9
Glasgow, Mo	231	21	11.8	1	8.1	28,30	9.3	3.7
Boonville, Mo	199	20	12.1	1	8.3	29,30	9.5	3.8
Hermann, Mo	103	24	10.7	1	6.1	30	7.6	4.6
Minnesota River.								
Mankato, Minn	127	18	3.5	1	2.3	27-29	2.6	1.2
St. Croix River.								
Stillwater, Minn	23	11	3.7	3	2.2	18-20	2.7	1.5
Illinois River.								
La Salle, Ill	197	18	11.8	1	11.4	14-17	11.6	0.4
Peoria, Ill	135	14	8.4	1	7.7	26,27,30	7.9	0.7
Conemaugh River.								
Johnstown, Pa	64	7	0.5	1-3,29,30	0.3	10-28	0.4	0.2
Allegheny River.								
Warren, Pa	177	14	− 0.4	1	− 0.7	27,28	−0.5	0.3
Parker, Pa	73	20	0.1	1-3	− 0.5	23-30	−0.3	0.6
Freeport, Pa	29	20	0.7	1,2,7	0.2	21,22, 25-28	0.4	0.5
Springdale, Pa	17	27	5.6	1	5.0	23	5.3	0.6
Youghiogheny River.								
Confluence, Pa	59	10	0.1	1-8	− 0.6	21-29	−0.3	0.7
West Newton, Pa	15	23	0.2	1	− 0.2	24-28	0.0	0.4
Monongahela River.								
Fairmont, W. Va	119	25	13.9	1-9	11.4	30	13.2	2.5
Greensboro, Pa	81	18	6.5	26	5.5	29,30	5.9	1.0
Lock No. 4, Pa	40	28	9.1	1,6	8.9	2	9.0	0.2
Muskingum River.								
Zanesville, Ohio	70	25	7.8	3-12	7.6	16-20, 23-27, 30	7.7	0.2
Little Kanawha River.								
Creston, W. Va	38	20	0.5	1	− 1.5	19-30	−1.0	2.0
New-Great Kanawha River.								
Hinton, W. Va	153	14	2.5	9	1.2	20,26-29	1.6	1.3
Charleston, W. Va	58	30	7.5	8	5.6	19	6.6	1.9
Scioto River.								
Columbus, Ohio	110	17	1.8	1,2	1.6	7-30	1.6	0.2
Licking River.								
Falmouth, Ky	30	25	1.0	23-30	0.0	19,20	0.5	1.0
Kentucky River.								
Beattyville, Ky	254	30	3.9	6	− 0.3	27-30	0.4	4.2
Frankfort, Ky	65	31	6.7	9	4.7	29,30	5.4	2.0
Wabash River.								
Mount Carmel, Ill	75	15	1.3	15,16	0.3	12	0.8	1.0
Cumberland River.								
Burnside, Ky	518	50	4.2	8	− 0.8	28-30	0.6	5.0
Celina, Tenn	383	45	4.8	10	0.6	29,30	1.6	4.2
Carthage, Tenn	308	40	5.3	6	0.4	30	1.4	4.9
Nashville, Tenn	193	40	12.3	6	7.0	29,30	8.0	5.8
Clarksville, Tenn	126	43	12.1	7	1.3	28	3.5	10.8
Clinch River.								
Speers Ferry, Va	156	20	5.5	6	− 0.2	28	0.6	5.7
Clinton, Tenn	52	25	10.0	8	2.4	27	3.8	7.6
South Fork Holston River.								
Bluff City, Tenn	35	12	1.5	6	0.2	21,22,24, 25,27,28	0.4	1.3
Holston River.								
Rogersville, Tenn	103	14	2.5	7,8	1.4	26-28	1.8	1.1
French Broad River.								
Asheville, N. C	144	4	2.7	6	− 0.2	21-27	0.2	2.9
Dandridge, Tenn	46	12	2.7	7	0.6	27,28	0.8	2.1
Tennessee River.								
Knoxville, Tenn	635	12	3.2	7	0.3	19-28	1.0	2.9
Loudon, Tenn	590	25	2.8	8	0.8	25-30	1.4	2.0
Kingston, Tenn	556	25	3.9	9	1.2	26-30	2.0	2.7
Chattanooga, Tenn	452	33	4.9	10	1.5	30	2.7	3.4
Bridgeport, Ala	402	24	3.0	10,11	0.4	27-30	1.3	2.6
Guntersville, Ala	349	31	6.5	1	1.7	28-30	3.3	4.8
Florence, Ala	255	16	3.7	1	0.1	29,30	1.3	3.6
Riverton, Ala	225	26	6.9	1	1.4	29,30	3.2	5.5
Johnsonville, Tenn	95	21	5.8	2	1.6	30	3.4	4.2
Ohio River.								
Pittsburg, Pa	966	22	6.0	21,22	5.1	25	5.6	0.9
Coraopolis, Pa	956	25	9.4	9	7.8	21	8.8	1.6
Beaver Dam, Pa	937	27	1.7	1	0.8	27,28,30	1.3	0.9
Wheeling, W. Va	875	36	1.0	1	0.0	30	0.4	1.0
Parkersburg, W. Va	785	36	1.5	1	− 0.2	30	0.5	1.7
Point Pleasant, W. Va	703	39	1.7	4	0.5	21,22,27-30	1.0	1.2
Huntington, W. Va	660	50	4.9	1	2.5	23,27-30	3.3	2.4
Catlettsburg, Ky	651	50	3.9	1	2.6	20,28	3.0	1.3
Portsmouth, Ohio	612	50	5.1	1	1.8	28-30	2.7	3.3
Maysville, Ky	559	50	6.6	1	2.5	29,30	3.4	4.1
Cincinnati, Ohio	499	50	8.4	1	2.9	28	4.4	5.5
Madison, Ind	413	46	6.7	2	3.0	29,30	4.4	3.7
Louisville, Ky	367	28	3.8	3	2.6	9	3.2	1.2
Evansville, Ind	184	35	4.8	6,7	2.1	30	3.3	2.7
Mount Vernon, Ind	148	35	4.6	8,9	2.0	28,29	3.1	2.6
Paducah, Ky	47	40	4.8	9	2.4	30	3.5	2.4
Cairo, Ill	1	45	13.9	1	6.1	30	9.6	7.8
Neosho River.								
Iola, Kans	262	10	0.2	2	− 0.9	20-22	−0.5	1.1
Oswego, Kans	184	20	1.4	4	0.3	24-30	0.7	1.1
Fort Gibson, Okla	3	22	9.0	1,13	8.6	4,5	8.8	0.4
Canadian River.								
Calvin, Okla	99	10	4.4	30	3.1	18	3.7	1.3
Black River.								
Blackrock, Ark	67	12	3.0	1-3	2.2	20-22	2.5	0.8
White River.								
Calicorock, Ark	272	18	2.0	23,28,29	− 0.3	20	0.6	2.3
Batesville, Ark	217	18	4.0	29	1.7	19,20	2.5	2.3
Clarendon, Ark	75	30	11.0	2	7.9	21	9.0	3.1
Arkansas River.								
Wichita, Kans	832	10	− 1.2	4	− 2.1	21-27	−1.8	0.9
Tulsa, Okla	551	16	7.8	7	3.0	24	4.2	4.8
Webbers Falls, Okla	465	23	9.0	8,9	6.2	18-23,26	6.9	2.8
Fort Smith, Ark	403	22	9.1	9	4.7	16	5.8	4.4
Dardanelle, Ark	256	21	9.8	11	5.0	19-21	6.3	4.8
Little Rock, Ark	176	23	9.4	12	4.8	20,21	6.2	4.6
Pine Bluff, Ark	121	25	12.8	13	8.2	23	9.7	4.6
Yazoo River.								
Greenwood, Miss	175	38	3.3	1	1.8	20-22	2.4	1.5
Yazoo City, Miss	80	25	1.6	1	− 1.3	19,20	0.1	2.9
Ouachita River.								
Camden, Ark	304	39	9.0	28	3.4	11	4.4	5.6
Monroe, La	122	40	5.4	30	0.0	19-22	2.2	5.4
Red River								
Arthur City, Tex	688	27	9.3	29	6.3	17	7.2	3.0
Fulton, Ark	515	28	12.2	6	8.9	21	9.6	3.3
Shreveport, La	327	29	1.1	2,3	− 0.3	18,23	0.4	1.4
Alexandria, La	118	36	7.3	1	3.1	24,25	4.6	4.2

TABLE IV.—*Heights of rivers referred to zeros of gages*—Continued.

Stations.	Distance to mouth of river.	Flood stage on gage.	Highest water. Height.	Highest water. Date.	Lowest water. Height.	Lowest water. Date.	Mean stage.	Monthly range.
	Miles.	Feet.	Feet.		Feet.		Feet.	Feet.
Mississippi River.								
Fort Ripley, Minn	2,082	10	5.7	30	4.6	9-11	5.0	1.1
St. Paul, Minn.	1,954	14	4.0	2,6	3.0	16	3.5	1.0
Red Wing, Minn.	1,914	14	1.8	3-6	1.1	20-23	1.4	0.7
Reeds Landing, Minn.	1,884	12	1.6	1	0.9	20-26	1.2	0.7
La Crosse, Wis.	1,819	12	2.7	1-3, 7	1.9	23-26	2.3	0.8
Prairie du Chien, Wis.	1,759	18	2.9	1	2.0	23-26	2.4	0.9
Dubuque, Iowa	1,699	18	3.3	1	2.0	27	2.6	1.3
Clinton, Iowa	1,629	16	3.3	1	2.0	25-27	2.5	1.3
Leclaire, Iowa	1,609	10	1.5	1,2	0.8	25-28	1.1	0.7
Davenport, Iowa	1,593	15	3.1	1	1.9	26	2.3	1.2
Muscatine, Iowa	1,562	16	3.9	1	2.6	26, 27	3.0	1.3
Galland, Iowa	1,472	8	2.0	1, 2	1.0	21-30	1.3	1.0
Keokuk, Iowa	1,463	15	3.9	1	1.3	30	2.2	2.6
Warsaw, Ill.	1,458	18	7.0	1	4.3	26	5.2	2.7
Hannibal, Mo	1,402	13	5.0	2	2.3	25-27, 30	3.2	2.7
Grafton, Ill	1,306	23	6.9	3, 4	4.3	27-29	5.3	2.6
St. Louis, Mo	1,264	30	10.8	2,3	4.4	28, 29	6.8	6.4
Chester, Ill	1,189	30	9.9	3, 4	5.3	30	7.2	4.6
New Madrid, Mo.	1,003	34	12.0	1	5.6	30	8.4	6.4
Memphis, Tenn	843	33	11.0	2	5.7	27-30	8.2	5.3
Helena, Ark.	767	42	12.9	1-3	6.6	29, 30	9.9	6.3
Arkansas City, Ark.	635	42	14.9	1	7.3	27-29	11.4	7.6
Greenville, Miss.	595	42	12.0	1	6.8	29	9.4	5.2
Vicksburg, Miss.	474	45	13.2	1	5.5	30	9.7	7.7
Natchez, Miss.	373	46	15.9	1	8.8	30	12.5	7.1
Baton Rouge, La.	240	35	10.2	1	4.9	29	7.7	5.3
Donaldsonville, La	188	28	7.5	1	4.0	29	5.9	3.5
New Orleans, La.	108	18	5.9	17, 18	4.4	28, 29	5.3	1.5
Atchafalaya River.								
Simmesport, La.	127	41	13.8	1	4.7	30	8.8	9.1
Melville, La.	103	37	18.1	1	8.6	30	13.3	9.5
Morgan City, La.	19	8	5.5	19	2.8	29	4.3	2.7
Hudson River.								
Troy, N. Y.	154	14	4.5	29	1.7	27	3.0	2.8
Albany, N. Y.	147	12	4.4	29	0.8	20	2.5	3.6
Delaware River.								
Hancock (E. Branch), N. Y.	287	12	3.4	30	2.3	18-23, 26-28	2.4	1.1
Hancock (W. Branch), N. Y.	287	10	3.0	30	2.2	3-6, 8, 17-28	2.3	0.8
Port Jervis, N. Y.	215	14	2.0	30	0.6	22, 23	0.8	1.4
Phillipsburg, N. J.	146	26	1.1	30	− 0.3	20-28	−0.1	1.4
Trenton, N. J.	92	18	1.0	30	0.1	24-28	0.3	0.9
North Branch Susquehanna.								
Binghamton, N. Y.	183	14	1.8	1, 3, 30	1.4	20	1.6	0.4
Wilkes-Barre, Pa.	60	17	2.4	29	2.0	17-18	2.1	0.4
West Branch Susquehanna.								
Williamsport, Pa.	39	20	0.5	1	0.2	13-28	0.3	0.3
Susquehanna River.								
Harrisburg, Pa.	69	17	1.1	30	0.2	28	0.4	0.9
Shenandoah River.								
Riverton, Va.	58	22	0.4	1	− 1.0	23-28	−0.6	1.4
Potomac River.								
Cumberland, Md.	290	8	2.0	1-8	1.6	11-30	1.7	0.4
Harpers Ferry, W. Va.	172	18	1.0	1-3	− 1.2	23-27	−0.2	2.2
James River.								
Lynchburg, Va.	260	20	2.2	6	0.5	23-28	0.9	1.7
Columbia, Va.	167	18	10.0	6	3.4	26, 27	5.1	6.6
Richmond, Va.	111	10	4.4	7	0.0	19, 23, 26	0.8	4.4
Dan River.								
Danville, Va	55	8	1.7	7	− 0.2	21-27	0.1	1.9
Roanoke River.								
Clarksville, Va	196	12	3.6	7	0.0	21-23, 26, 27	0.8	3.6
Weldon, N. C.	129	30	22.3	1	10.3	23	12.5	12.0
Tar River.								
Greenville, N. C.	21	22	19.4	2	4.2	29, 30	8.5	15.2
Deep River.								
Moncure, N. C.	171	25	18.6	6	1.3	21-23	4.8	17.3
Cape Fear River.								
Fayetteville, N. C	112	38	37.0	1	3.6	27	12.4	33.4
Pedee River.								
Smiths Mills, S. C.	51	16	24.0	3,4	3.5	30	13.4	20.5
Lynch Creek.								
Effingham, S. C.	35	12	17.0	1	3.6	27, 28	7.5	13.4
Black River.								
Kingstree, S. C.	45	12	6.9	1	0.2	26, 27	3.3	6.7
Catawba-Wateree River.								
Mount Holly, N. C.	143	15	4.0	6	1.8	9-28, 30	2.0	2.2
Catawba, S. C	107	11	6.5	7	2.2	20, 24	3.0	4.3
Camden, S. C.	37	24	25.0	7	6.7	18	10.8	18.3
Congaree River.								
Columbia, S. C	52	15	8.6	7	1.3	11	2.9	7.3
Santee River.								
Ferguson, S. C.	82	12	23.0	1	7.4	26-28	11.9	15.6
Savannah River.								
Calhoun Falls, S. C.	347	15	5.3	5	2.5	26	3.1	2.8
Augusta, Ga.	268	32	20.0	7	8.0	22, 27	9.9	12.0
Oconee River.								
Dublin, Ga	79	30	20.1	1	0.1	21, 26	2.9	20.0
Ocmulgee River.								
Macon, Ga.	134	18	9.9	7	2.1	26-28	3.3	7.8
Abbeville, Ga.	51	11	11.6	2	2.0	22-24	4.6	9.6
Flint River.								
Montezuma, Ga.	152	20	7.4	9	1.7	22	3.6	5.7
Albany, Ga.	99	20	7.9	1	1.3	19, 20	3.1	6.6
Bainbridge, Ga.	22	22	11.0	1, 2	5.1	23	6.9	5.9
Chattahoochee River.								
West Point, Ga	174	20	5.6	7	1.8	20, 21, 26-30	2.4	3.8
Eufaula, Ala	90	40	8.6	9	0.5	20	2.2	8.1
Alaga, Ala.	30	25	8.6	9	2.8	19, 20	4.0	5.8
Coosa River.								
Rome, Ga.	266	30	5.0	6.7	0.3	29, 30	1.0	4.7
Gadsden, Ala.	162	22	5.7	8	0.4	29, 30	1.4	5.3
Lock No. 4, Ala.	113	17	4.2	8	0.3	21-23, 27-30	1.0	3.9
Wetumpka, Ala	12	45	7.2	10	1.0	30	2.5	6.2
Alabama River.								
Montgomery, Ala.	323	35	4.4	10	0.1	29, 30	1.3	4.3
Selma, Ala	246	35	5.1	11	− 0.5	26	1.1	5.6
Black Warrior River.								
Tuscaloosa, Ala.	90	43	5.7	10	4.3	19	4.8	1.4
Tombigbee River.								
Columbus, Miss	316	33	− 0.3	23, 24	− 3.3	18-22	−2.7	3.0
Demopolis, Ala.	168	35	1.0	1	− 2.4	21	−0.8	3.4
Pascagoula River.								
Merrill, Miss.	78	20	4.0	24, 25	1.3	21	2.2	2.7
Pearl River.								
Columbia, Miss.	110	18	4.8	1, 2	3.3	20, 21	3.9	1.5
Sabine River.								
Logansport, La.	315	25	12.0	27	1.6	18-20	4.3	10.4
Neches River.								
Beaumont, Tex.	18	10	3.2	21	0.7	28	1.8	2.5
Trinity River.								
Dallas, Tex.	320	25	11.7	29	4.6	12, 13	6.5	7.1
Long Lake, Tex.	211	35	27.0	1	2.8	16	9.9	24.2
Liberty, Tex	20	25	16.7	7	5.9	17	9.2	10.8
Brazos River.								
Waco, Tex.	285	22	6.0	17	2.4	11	3.7	3.6
Hempstead, Tex	140	40	7.5	24	1.0	16	3.8	6.5
Booth, Tex	61	39	5.7	2	4.6	27-30	5.3	1.1
Colorado River.								
Austin, Tex.	214	18	4.6	21	1.5	2-7	2.5	3.1
Columbus, Tex.	98	24	9.9	23	6.6	8, 11, 12	7.8	3.3
Red River of the North.								
Moorhead, Minn	284	26	8.5	1-6	7.9	18, 19	8.2	0.6
Rio Grande.								
San Marcial, N. Mex.*	1,233	11	10.2	1	8.7	17	9.1	1.5
El Paso, Tex.†	1,030	14	12.2	5	8.5	21	9.9	3.7
Snake River.								
Lewiston, Idaho	144	24	1.5	20	1.0	8, 12-14	1.2	0.5
Riparia, Wash.	67	30	2.4	20, 21	1.2	1-4	1.8	1.2
Columbia River.								
Wenatchee, Wash	473	40	14.0	1	8.9	30	11.3	5.1
Umatilla, Oreg	270	25	6.6	1	3.6	30	4.8	3.0
The Dalles, Oreg.	166	40	9.0	1	4.5	30	6.2	4.5
Willamette River.								
Albany, Oreg.	118	20	1.3	1, 2	0.7	28-30	0.9	0.6
Portland, Oreg.	12	15	5.2	12	2.0	30	3.4	3.2
Sacramento River.								
Red Bluff, Cal.	265	23	0.8	17, 19	0.5	1-16	0.6	0.3
Colusa, Cal.	156	28	2.4	21	2.0	1-17, 26-30	2.1	0.4
Knights Landing, Cal.	99	18	0.6	20-24	0.2	29, 30	0.4	0.4
Sacramento, Cal.	64	25	5.6	8-12, 23-25	5.3	3, 18, 29, 30	5.5	0.3
San Joaquin River.								
Pollasky, Cal.	203	10	0.2	15, 24	0.0	‡	0.0	0.2
Firebaugh, Cal	148	14	− 1.1	12-15, 29, 30	− 1.4	3-10, 21-27	−1.3	0.3
Lathrop, Cal.	49	14	1.0	25	0.0	1, 2, 12, 13, 17, 27-30	0.4	1.0

* 18 days only. † 21 days only. ‡ Various dates.

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Honolulu, T. H., latitude 21° 19′ north, longitude 157° 52′ west; barometer above sea, 38 feet; gravity correction, —0.057 inch, applied. September, 1908.

Day.	Pressure, in inches.*		Air temperature, degrees Fahrenheit.				Moisture.				Wind, in miles per hour.				Precipitation, inches.		Clouds.					
							8 a. m.		8 p. m.		8 a. m.		8 p. m.				8 a. m.			8 p. m.		
	8 a. m.	8 p. m.	8 a. m.	8 p. m.	Maximum.	Minimum.	Wet.	Relative humidity.	Wet.	Relative humidity.	Direction.	Velocity.	Direction.	Velocity.	8 a. m.	8 p. m.	Amount.	Kind.	Direction, from.	Amount.	Kind.	Direction, from.
							°	%	°	%												
1	30.04	30.05	77.0	76.0	80	71	72.0	79	70.0	74	e.	9	se.	3	0.21	0.38	10	N.	e.	3 4	A.-s. A.-cu.	0 ? 0 ?
2	30.06	29.99	77.0	74.8	81	73	67.0	59	67.0	67	e.	5	e.	9	......	......	4	Cu.	ne.	Few	Cu.	ne.
3	30.00	29.99	76.3	75.0	81	72	68.0	65	68.0	70	ne.	4	ne.	5	......	......	5	Cu.	e.	8	Cu.	ne.
4	30.02	30.01	78.1	74.5	81	71	69.0	63	68.6	72	nw.	2	ne.	6	......	......	1 1	Ci. Cu.	nw. e.	8	Cu.	ne.
5	30.04	30.05	76.1	75.0	81	72	68.3	67	69.0	74	s.	2	e.	6	......	......	9	S.-cu.	ne.	10	Cu.	ne.
6	30.06	30.05	78.0	76.2	83	73	68.2	61	69.2	70	ne.	5	e.	2	......	......	1 1	Ci. Cu.	sw. e.	6 1	Ci.-cu. Cu.	nw. n.
7	30.07	30.07	79.0	75.8	82	74	69.0	60	69.0	71	ne.	10	e.	2	......	......	2 Few	Ci. Cu.	sw. e.	10	A.-s.	0 ?
8	30.08	30.05	77.2	76.0	82	74	63.0	66	68.3	67	e.	5	e.	8	......	......	7 2	Ci.-cu. Cu.	w. e.	1	A.-s.	0 ?
9	30.08	30.06	77.0	76.0	82	74	68.0	63	68.0	66	e.	8	e.	4	......	......	8	S.-cu.	e.	5 9	Cu. Cu.	ne. e.
10	30.09	30.05	76.5	76.0	82	72	68.0	64	68.5	68	ne.	5	e.	10	T.	......	9	S.-cu.	e.	3	Cu.	ne.
11	30.07	30.03	77.0	75.0	82	73	67.0	59	67.0	66	ne.	5	ne.	12	......	......	4	Cu.	e.	1	Cu.	ne.
12	30.04	30.03	76.4	75.0	82	73	68.1	65	68.5	72	ne.	17	ne.	5	......	......	Few Few	A.-cu. Cu.	0 ? 0 ?	0	0	0
13	30.09	30.03	76.0	75.0	82	70	69.0	70	69.0	74	ne.	5	ne.	8	0.03	T.	4	N.	e.	1	S.	e.
14	30.05	30.05	77.2	75.0	81	72	67.6	61	69.0	74	ne.	8	ne.	6	......	0.01	5	Cu.	e.	1	S.	e.
15	30.05	30.05	75.0	74.0	82	71	69.4	76	70.0	82	e.	13	e.	7	0.02	0.03	5	S.-cu.	ne.	6	S.	e.
16	30.07	30.06	77.0	75.5	82	72	68.0	63	68.0	68	ne.	5	e.	9	0.03	......	4 1	Ci.-s. Cu.	w. e.	5	S.	e.
17	30.06	30.05	76.4	76.0	82	73	67.1	62	67.0	62	ne.	10	e.	5	......	......	5	Cu.	ne.	2	S.	e.
18	30.02	30.00	77.0	76.0	81	73	68.1	63	70.0	74	ne.	14	ne.	12	......	0.03	2	Cu.	e.	5	N.	e.
19	29.98	29.99	79.0	75.0	81	74	72.2	72	69.2	75	ne.	11	e.	10	0.03	0.03	5	Cu.	ne.	6	S.	e.
20	29.99	29.96	77.0	75.5	81	72	67.0	59	68.0	68	ne.	6	ne.	10	......	......	5 Few	Ci.-s. Cu.	w. e.	2	A.-s.	0 ?
21	29.99	29.98	79.0	76.0	82	74	69.0	60	68.0	66	ne.	4	e.	5	......	......	1	Cu.	e.	Few Few	A.-s. Cu.	0 ? e.
22	30.03	30.02	79.0	76.5	83	74	69.0	60	70.0	72	e.	9	e.	7	......	......	5 1	Ci. Cu.	nw. e.	8	S.	e.
23	30.02	29.98	78.0	76.0	84	75	68.1	60	69.0	70	ne.	12	ne.	7	......	......	7 1	A.-cu. Cu.	w. e.	0	0	0
24	29.98	29.95	77.0	75.5	83	73	69.0	67	68.0	68	e.	8	ne.	7	......	......	9 1	A.-s. Cu.	0 e.	2	S.	e.
25	30.01	30.00	78.8	74.5	80	70	69.4	62	70.0	80	ne.	2	ne.	2	......	......	5 1	Ci.-cu. Cu.	w. e.	0	0	0
26	30.01	30.05	75.0	76.0	82	70	70.0	78	70.0	74	nw.	1	ne.	12	......	......	9 1	A.-s. Cu.	0 0	4	S.	e.
27	30.04	30.01	76.6	76.0	82	72	69.0	70	69.0	70	ne.	6	e.	5	......	......	2 7	Ci. S.-cu.	0 e.	Few 1	A.-s. S.	0 ? e.
28	29.99	29.97	76.4	72.8	81	71	69.0	69	69.0	83	ne.	13	e.	3	......	0.02	4	Cu.	e.	3	S.	ne.
29	29.96	29.93	73.0	76.0	80	70	68.3	79	68.0	66	se.	4	e.	8	0.04	T.	9	N.	e.	1	A.-s.	n.
30	30.00	30.02	78.0	76.0	81	73	69.0	63	70.0	74	e.	8	ne.	3	0.01	......	2	Cu.	e.	7	Cu.	ne.
31	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Mean	30.033	30.018	77.0	75.4	81.6	72.4	68.7	65.5	68.7	71.2	ne.	7.2	e.	6.6	0.37	0.50	5.5	Cu.	e.	4.1	Cu.-s.	e.

Observations are made at 8 a.m. and 8 p. m., local standard time, which is that of 157° 30′ west, and is 5h and 30m slower than 75th meridian time. *Pressure values are reduced to sea level and standard gravity.

RAINFALL IN JAMAICA.

Thru the kindness of Mr. Maxwell Hall, meteorologist to the government of Jamaica and now in charge of the meteorological service of that island, we have received the following data:

Comparative table of rainfall.

[Based upon the average stations only.]

SEPTEMBER, 1908.

Divisions.	Relative area.	Number of stations.	Rainfall.	
			1908.	Average.
	Per cent.		*Inches.*	*Inches.*
Northeastern division	25	21	5.69	8.59
Northern division	22	49	4.89	5.13
West-central division	26	19	9.72	10.60
Southern division	27	30	3.69	6.28
Means	100	......	6.00	7.65

The rainfall over the island for September, 1908, was about the average, and the forecast was therefore verified. The greatest rainfall recorded was 17.70 inches, at Castle Gardens, and the smallest recorded was 0.26 inch, at Plumb Point lighthouse.

At Georgetown, Grand Cayman, the total rainfall was 2.99 inches, on 10 days; the greatest fall in 24 hours was 1.43 inches, on the 3d.

Chart I. Hydrographs for Seven Principal Rivers of the United States, September, 1908.

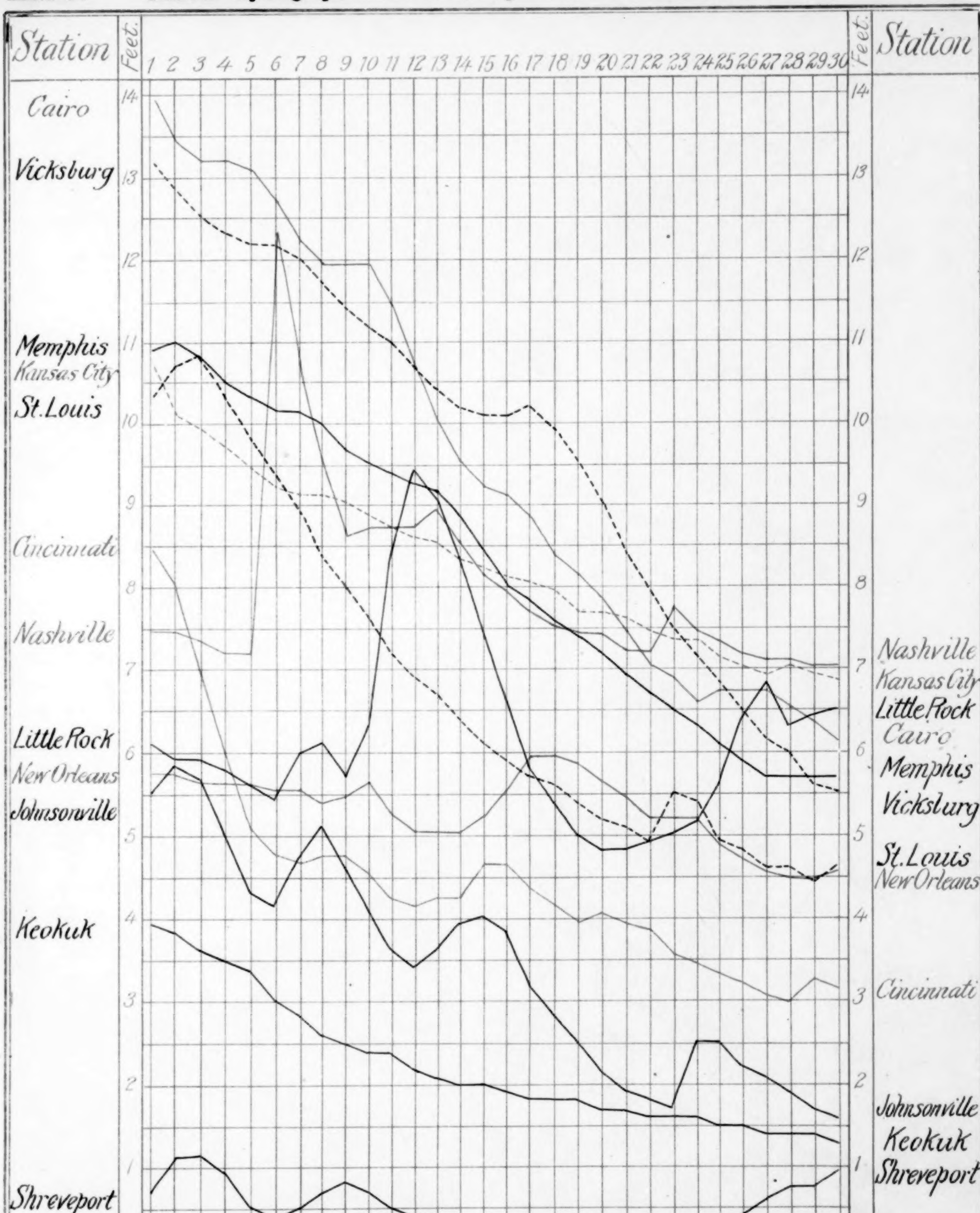


Chart II. Tracks of Centers of High Areas, September, 1908.

Chart III. Tracks of Centers of Low Areas, September, 1908.

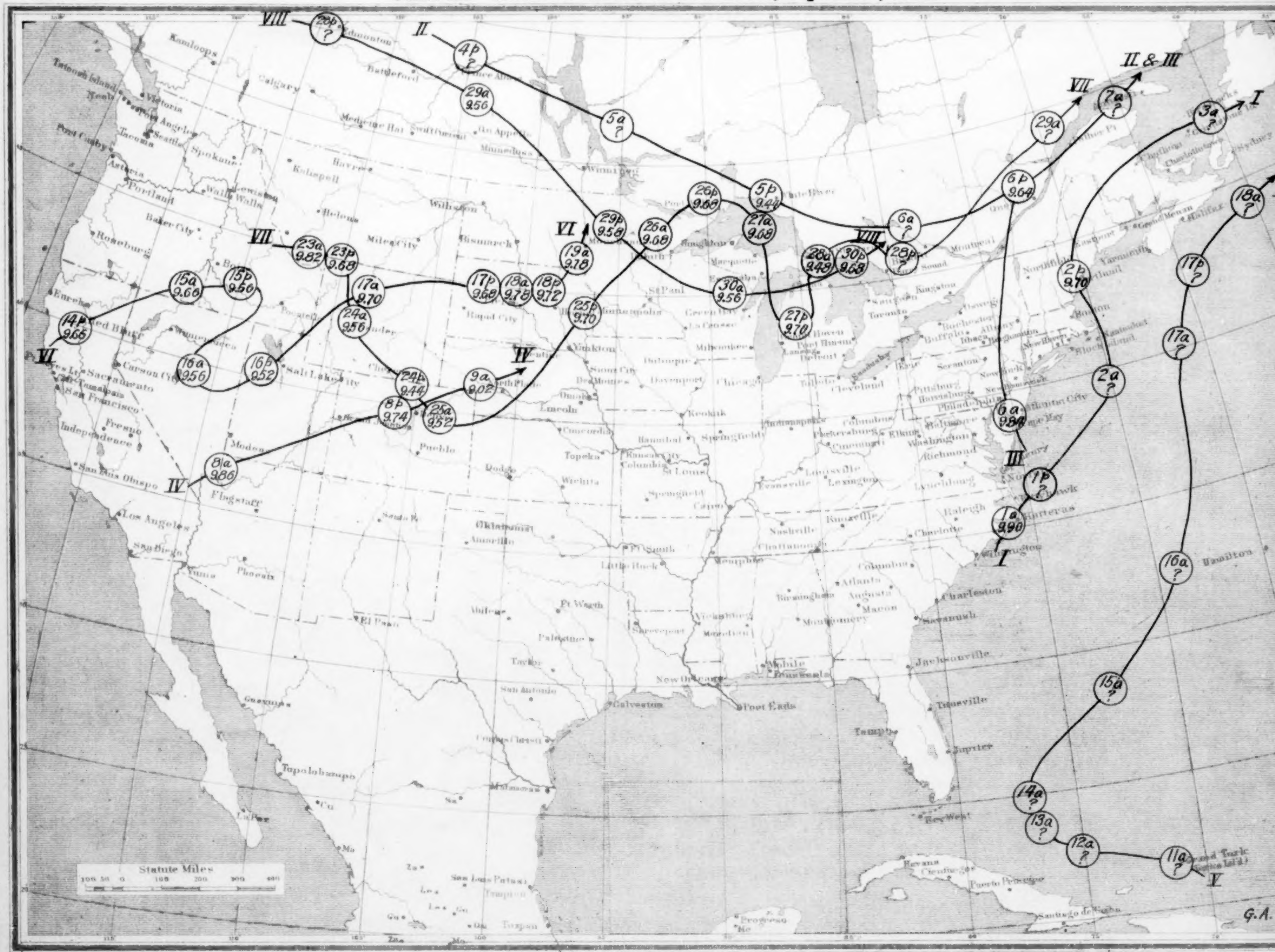
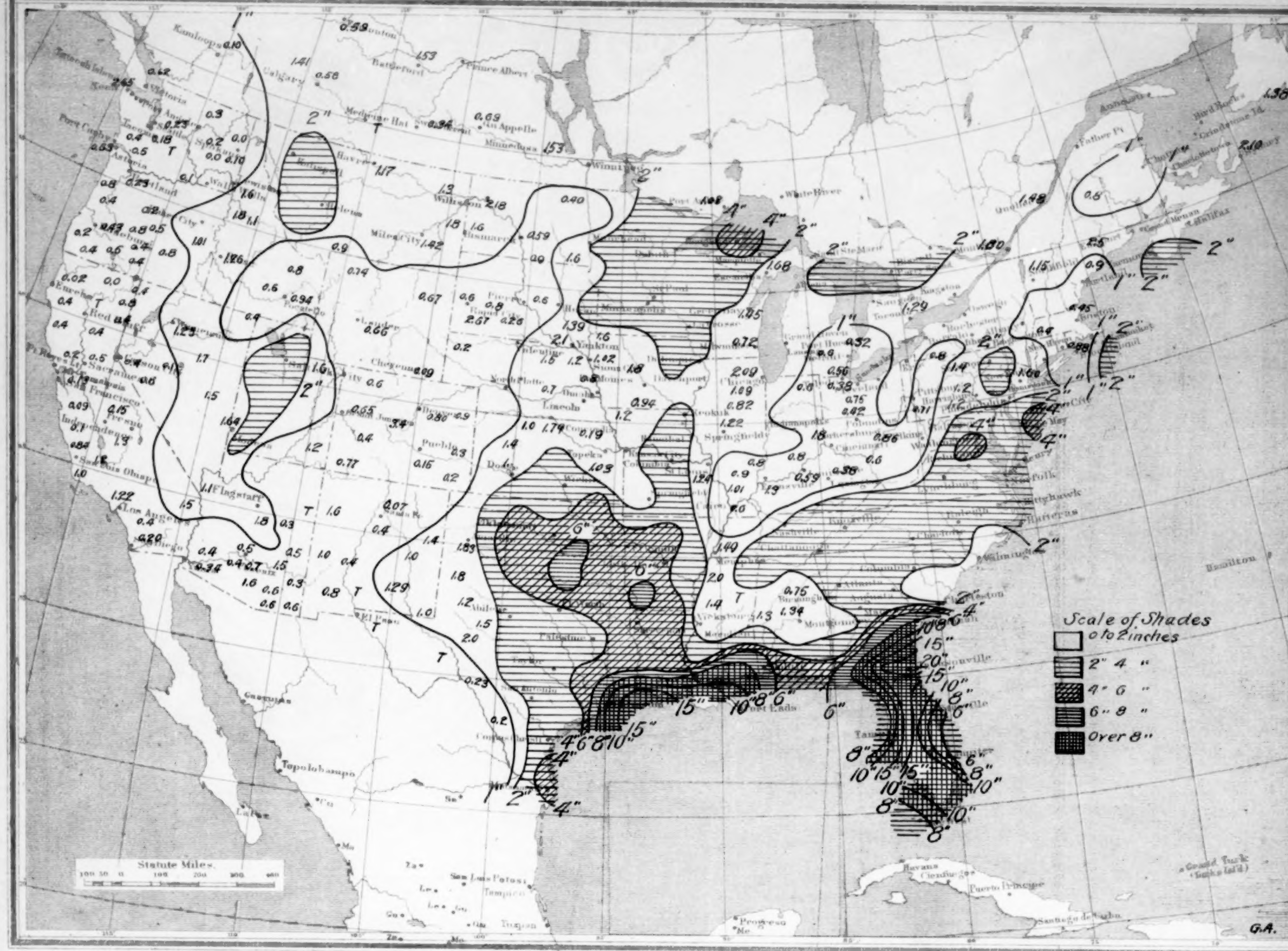


Chart IV. Total Precipitation, September, 1908.



XXXVI—93. Chart V. Percentage of Clear Sky between Sunrise and Sunset, September, 1908.

Chart V. Percentage of Clear Sky between Sunrise and Sunset, September, 1908.

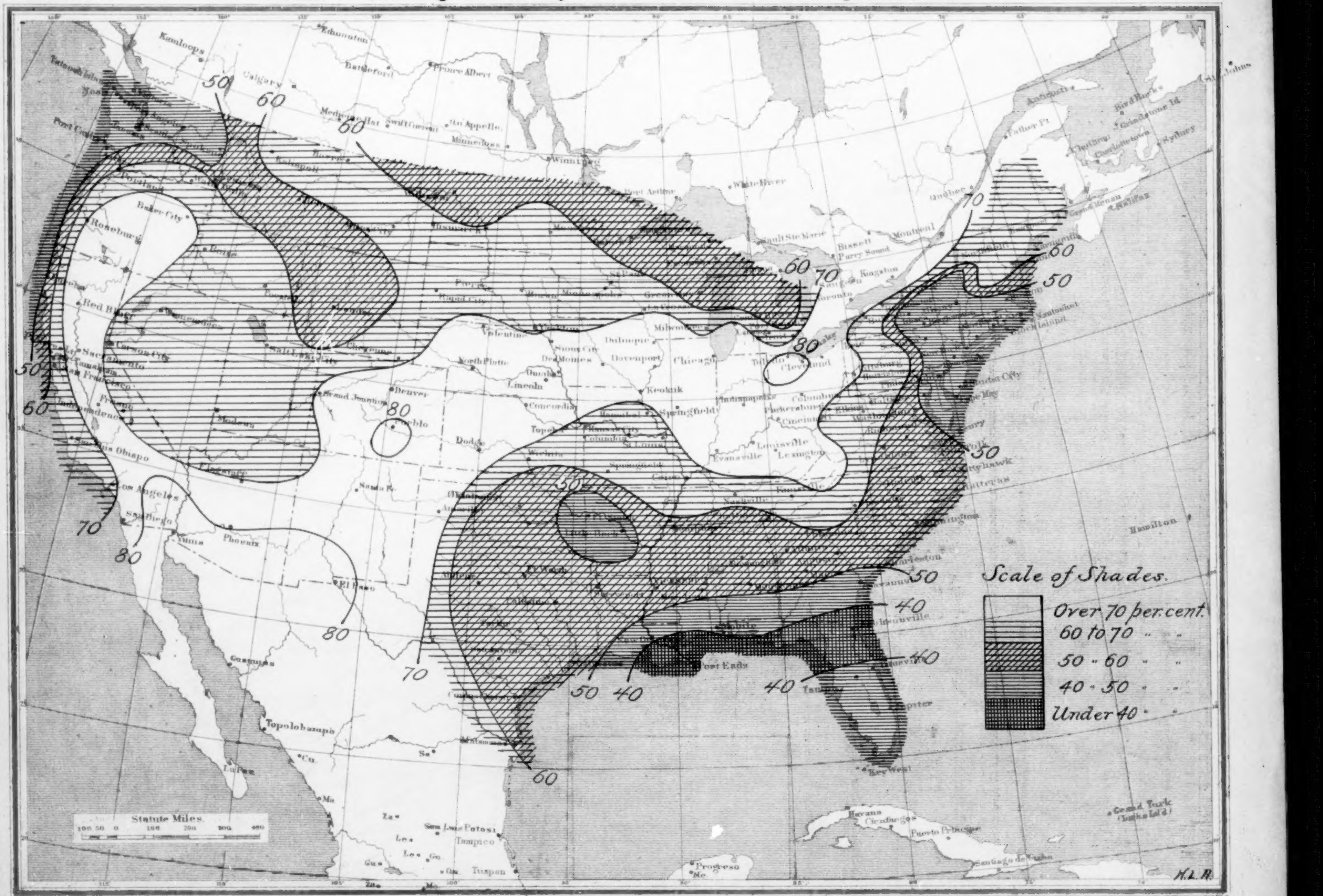


Chart VI. Isobars and Isotherms at Sea Level; Prevailing Winds, September, 1908.

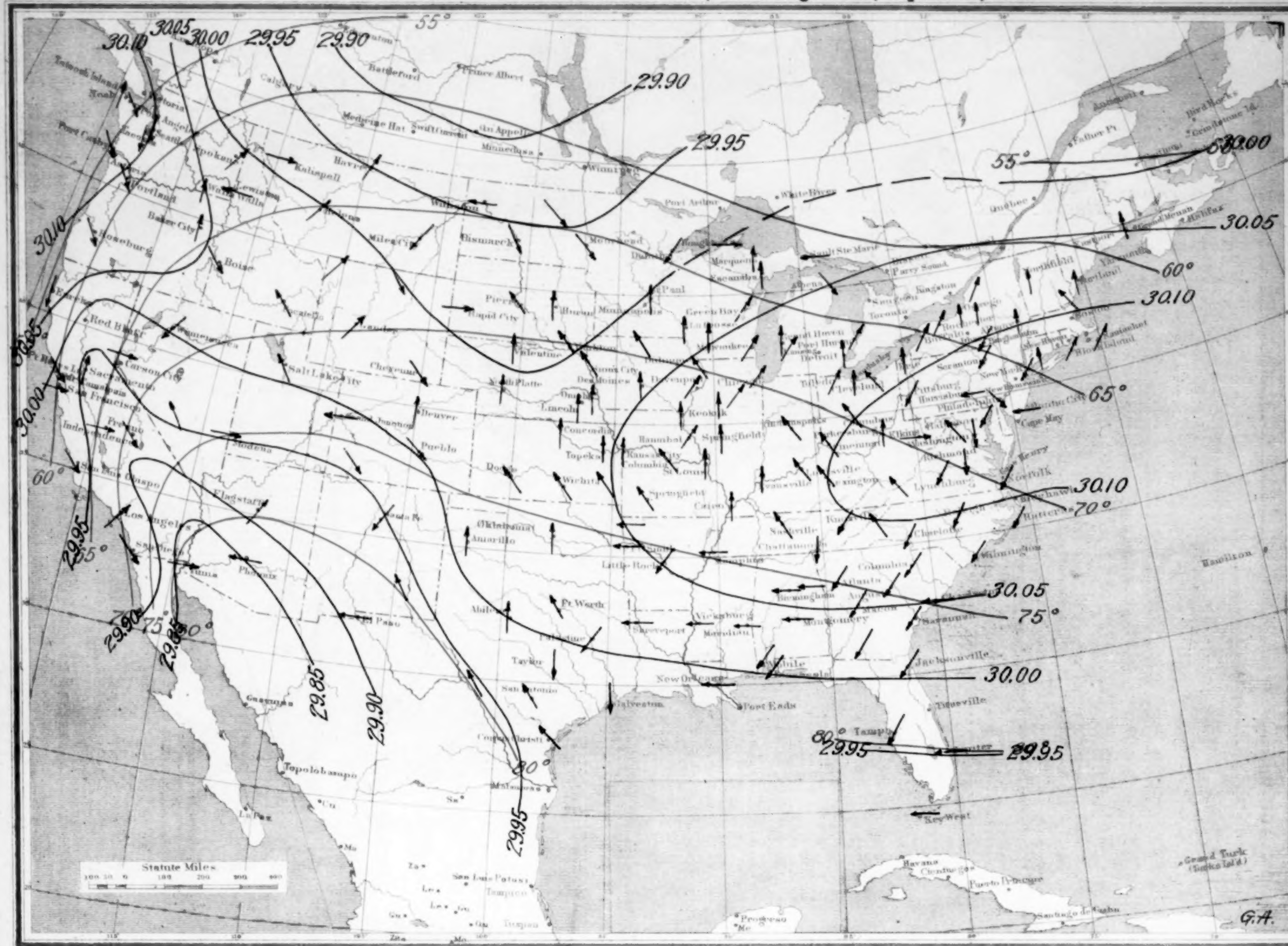


Chart IX. Observações Meteorológicas Simultaneas a 0^h_m de Greenwich ($9^h\ 07^m$ a. t. m. do Rio).

15 d Jullio de 1908.

This symbol is read, cloudiness 5, wind S.W, force 7.